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CONSUMPTION AND WASTE OF WATER.

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WITH DISCUSSION.

An examination of the annual reports of the water departments of the cities of the United States shows that the quantity of water used has increased much more rapidly than the growth of the population, and much more rapidly than had been expected by the engineers who designed the works. Take the case of Boston, which may be considered typical of many other cities. The original works were constructed in 1848, and were based upon the assumption that 28 galls. per capita would be an adequate supply for all purposes, this conclusion being based on the experience of the city of Philadelphia. Before many years it was discovered that 28 galls. per capita were not sufficient, and in estimating for an additional supply in 1872, J. P. Davis, M. Am. Soc. C. E., considered that 60 galls. for each person would be a proper allowance for future needs. The present consumption in Boston is about 100 galls. per inhabitant; the capacity of the supply obtained

TABLE No. 1.

Daily Average Consumption of Water in Gallons per Capita per Day in Various Cities in the United States.

	Years.	Boston, Cochituate Works.	Boston, Mystic Works.	Chicago.	Philadelphia.	Brooklyn.	St. Louis.	Cincinnati.	Cleveland.	Detroit.
Population.	1850	139 800	.....	29 963	121 376	96 838	77 860	115 435	17 034	21 019
	1860	177 900	.....	112 172	565 529	266 661	160 773	161 044	43 417	45 619
	1870	225 100	87 071	298 997	674 022	396 099	310 864	216 039	92 829	79 577
	1880	306 000	107 700	503 185	847 170	566 663	350 518	255 139	160 146	116 340
	1890	410 130	117 500	1 099 850	1 046 964	806 343	451 770	296 908	261 353	205 876
Daily Average Consumption.	1850	42	.....	.....	.....	.....	.....	20	.....	.....
	1855	64	.....	.....	.....	.....	.....	25	.....	44
	1860	97	.....	43	36	.....	.....	30	14	52
	1865	66	27	42	50	29	.....	29	22	55
	1870	66	44	73	55	47	.....	48	31	64
	1871	60	56	72	55	47	.....	53	36	76
	1872	63	70	74	54	53	45	54	40	88
	1873	72	77	88	56	59	51	50	43	98
	1874	72	73	96	58	54	55	55	45	97
	1875	69	86	100	69	59	61	60	44	120
	1876	71	80	103	.....	57	62	68	49	111
	1877	72	75	.....	58	59	66	64	56	111
	1878	80	76	123	64	58	67	66	51	110
	1879	87	88	.....	66	60	72	68	63	125
	1880	87	87	112	68	54	72	76	65	130
	1881	94	80	.....	71	56	76	87	77	145
	1882	95	73	110	76	58	76	69	68	132
	1883	97	74	.....	76	58	75	66	76	146
	1884	73	65	114	74	61	63	74	83	159
	1885	73	68	116	72	64	67	64	93	176
	1886	74	72	118	80	65	73	74	91	176
	1887	80	72	120	89	65	73	88	96	197
	1888	87	75	119	100	67	74	99	95	204
	1889	81	69	123	110	67	73	99	99	172
	1890	83	71	127	132	68	78	115	106	155
	1891	90	75	135	140	70	83	138	111	144
	1892	96	79	134	143	79	89	123	118	140
	1893	107	86	147	150	86	95	124	130	148
	1894	101	89	.....	.....	.....	.....	.....	.....	144

TABLE No. 1—(*Continued*).

	Years.	Milwaukee.	Louisville.	Providence.	Lowell.	Fall River.	Cambridge.	Lynn.	New Bedford.	Salem.
Population.	1850	20 061	43 194	41 513	33 383	11 524	15 215	14 257	16 443	20 264
	1860	45 246	68 033	50 666	36 827	14 026	26 060	19 083	22 300	22 252
	1870	71 440	100 753	68 904	40 928	26 766	39 634	28 233	21 320	24 117
	1880	115 587	123 758	104 857	59 475	48 961	52 669	38 274	26 845	27 563
	1890	204 468	161 129	132 146	77 696	74 308	70 028	55 727	40 733	30 801
Daily Average Consumption.	1850									
	1855									
	1860									
	1865		18							
	1870		23				44			31
	1871		21				43			38
	1872		22				38			45
	1873		22				48	41		55
	1874		24			12	50	42		51
	1875	29	24		24	18	57	40		
	1876	45	27		29	25	51	32		59
	1877	69	29	24	30	26	53	32		58
	1878	85	30	26	32	25	45	32		53
	1879	96	33	30	35	27	47	34		55
	1880	106	42	34	38	28	46	32		55
	1881	109	56	35	40	30	46	32	86	59
	1882	114	47	33	43	36	45	37	82	63
	1883	108	52	37	46	31	47	36	78	61
	1884	101	56	34	48	26	46	39	72	60
	1885	105	62	37	56	26	51	42	85	62
	1886	110	65	37	59	27	56	44	86	64
	1887	117	64	37	62	25	60	48	85	77
	1888	105	62	40	69	28	63	45	88	71
	1889	116	67	41	62	27	62	43	89	68
	1890	114	71	46	69	28	65	45	98	69
	1891	112	78	48	74	30	67	49	92	87
	1892	101	81	57	73	27	71	53	88	81
	1893	108	75	63	79	27	80	54	91	66
	1894				75		70			

in 1872 will soon be reached, and the Massachusetts State Board of Health, in a report on the water supply for the Boston Metropolitan District, has come to the conclusion that 100 galls. per capita is a proper allowance for the future needs of the district which embraces all the cities and towns within 12 miles of the State House.

Although the present consumption in Boston is about four times as large as the estimate of the designers of the works, it is still less than that of a number of large American cities. The table on pages 186 and 187 gives the per capita consumption in some of the cities of the United States and shows the great increase which has taken place, especially during the past five years.

The question naturally arises, what are the causes of this great and constantly increasing use of water? Is the increase due to a legitimate use, or is it due to a wasteful and extravagant use of the water? The author is of the opinion that the increase can be attributed in part to both of these causes, but that the greatest cause is the unnecessary and wilful waste.

With a few exceptions the efforts of the authorities in charge of water supplies during the past 25 or 30 years have been directed toward the securing of new sources of supply and the construction of additional works, rather than toward the promotion of measures of economy in the use of the supplies already provided. Public opinion has always favored the free use of water, and in most cities there exists a well-established but mistaken idea that constant streams of water running through water-closets and house drains have a tendency to prevent or remove the formation of noxious gases and disease germs.

In the following paper an attempt has been made to study the causes of the great increase in the consumption of water, with the object of learning: *First*, what can be considered a proper allowance per capita in designing works for future supply? *Second*, what are the causes of waste and how can it be best prevented?

Consumption per Capita.—In considering the proper allowance to be made for the use of water, it will be convenient to consider the question under the following subdivisions:

Quantity used for domestic purposes.

Quantity used for trade, manufacturing and mechanical purposes.

Quantity used for public purposes.

Quantity wasted.

Quantity Used for Domestic Purposes.—Under the first head should be included not only the household uses of the inhabitants, but also the quantity required for provision stores, fish markets, laundries and stables, in fact, all the requirements of a residential community, with the exception of the public uses of fountains, street watering, fires, etc.

TABLE No. 2.

CONSUMPTION PER CAPITA IN BOSTON, BROOKLINE, NEWTON, FALL RIVER, WORCESTER, YONKERS AND LONDON, AS DETERMINED BY METER MEASUREMENT.

CITY OR TOWN.	Number of houses.	Number of families.	Number of persons.	CONSUMPTION, GALLONS PER—		REMARKS.
				Family.	Capita.	
Boston.....	31	402	1 461	221	59	Highest cost apartment houses in the city.
Boston.....	46	628	2 524	185	46	First-class apartment houses.
Boston.....	223	2 204	8 432	123	32	Moderate class apartment houses.
Boston.....	39	413	1 844	80	16.6	Poorest class apartment houses.
Boston.....	339	3 647	14 261	139	35.6	Average of all apartment houses supplied by meter.
Boston.....	40	....	1 699	....	46.1	Boarding houses.
Brookline...	..	828	4 140	221.5	44.3	Average of all dwellings supplied by meter.
Newton	490	490	2 450	132.5	26.5	All houses supplied with modern plumbing.
Newton	....	619	3 005	....	6.6	These families have but one faucet each.
Newton	....	278	1 390	34.5	6.9	These families have but one faucet each.
Fall River.....	28	34	170	127.5	25.5	The most expensive houses in the city.
Fall River.....	64	148	740	42.0	8.4	Average class of houses, generally having bath and water-closet.
Fall River.....	....	....	70 000	....	12.3	Total domestic consumption.
Worcester.....	....	20 514	90 942	....	16.8	Whole domestic consumption.
Worcester.....	....	81	327	80.2	19.9	Woodland street, best class of houses.
Worcester.....	....	37	187	119.1	23.4	Cedar street, best class of houses.
Worcester.....	....	93	447	95.0	19.8	Elm street, houses of moderate cost.
Worcester.....	....	245	1 104	55.1	12.2	Southbridge street, cheaper houses.
Worcester.....	....	229	809	55.0	15.6	Austin street, cheaper houses.
Yonkers, N. Y....	....	....	31 000		21.4	
London, England.	1 169	....	8 183	.....	25.5	Houses renting from $250 to $600; each have bath and two water-closets.
London, England.	727	....	5 089	.....	18.6	Middle class, average rental, $200.

The records obtained in cities and towns where water meters are used on house services furnish the best information obtainable in regard to the actual quantity needed for domestic purposes. Table No. 2 embodies the results of data collected, showing the actual con-

sumption per capita for household or domestic use by different classes of people in a number of cities, as determined by meter records.

There appears to be a marked difference in the household consumption in different places. In the case of Brookline, the average per capita consumption of 44.3 galls. includes the amount used for private stables, conservatories, lawns, etc., and the use for these purposes is very much larger in that town than in the average suburban community.

In Newton the consumption of 26.5 galls. per capita represents the quantity used by people residing in modern houses valued at from $5 000 to $15 000 and containing all the modern plumbing conveniences, but the houses are on smaller estates than many of those in Brookline and the number of stables and conservatories is much smaller.

The houses in Worcester and Fall River are, as a whole, much less expensive and have fewer water fixtures than those in Brookline and Newton. The figures given for London are taken from the Report of the Royal Commission on the Water Supply of the Metropolis. The consumption per capita in English cities is generally much smaller than in the United States, but these figures indicate that the actual quantities used in buildings having water fixtures of similar character are the same there as in our cities.

The per capita consumption in Newton, Fall River, Worcester and London, in first-class houses supplied with modern plumbing, was in each case about 25 galls. In two instances, Worcester 16.8 galls., and Fall River 12.3 galls., the figures given embrace not only the household consumption, but all domestic uses, including small stores, groceries, laundries and stables, in fact, every use with the exception of manufacturing, mechanical and public uses.

In Yonkers, N. Y., all of the water is supplied through meters, except for builders' use, street sprinkling, public buildings and street and sewer use. The number of consumers in 1894 was estimated to be 31 000, and the records of the meters show that the domestic consumption was 21.4 galls. per consumer.

It is worthy of notice that the averages in the table are not based upon the records of a few families. Combining all of the records, there is a population of 232 000 using 18.2 galls. per capita. With an addition of 10% to cover loss in the registration of the meters, the consumption per person would be but 20 galls.

TABLE No. 3.

TABLE SHOWING CONSUMPTION IN GALLONS PER CAPITA FOR VARIOUS PURPOSES FROM THE COCHITUATE WORKS IN BOSTON IN 1880 AND 1892.

	POPULATION, 1880, 306,000.			POPULATION, 1892, 430,000.		
	Metered.	Unmetered.	Total.	Metered.	Unmetered.	Total.
MANUFACTURES AND TRADE.						
Office buildings and stores	0.844	10.200	11.044	5.63	5.54	11.17
Steam railroads	1.139	.....	1.139	2.26	.....	2.26
Sugar refineries	0.811	.....	0.811	1.70	.....	1.70
Factories, machine shops, mills and engines	0.966	2.120	3.086	2.15	.....	2.15
Iron works and foundries	0.573	.....	0.573	0.24	.....	0.24
Marble and stone works	0.143	.....	0.143	0.12	.....	0.12
Gas companies	0.324	.....	0.324	0.75	.....	0.75
Electric light companies	.....	.....	.....	0.69	.....	0.69
Breweries	0.556	.....	0.556	0.89	.....	0.89
Oil and chemical works	0.214	.....	0.214	0.19	.....	0.19
Laundries	.....	0.150	0.150	0.15	0.35	0.50
Restaurants	0.129	0.650	0.779	0.37	0.29	0.66
Stables	0.443	.....	0.443	0.60	.....	0.60
Steamers and shipping	0.325	1.000	1.325	0.82	0.08	0.90
Elevators and motors	1.033	.....	1.033	2.95	.....	2.95
Street railways	.....	.....	.....	0.90	.....	0.90
Saloons	.....	1.500	1.500	0.27	0.89	1.16
Hotels	1.454	0.150	1.604	1.55	0.07	1.62
Theatres and halls	.....	.....	.....	0.10	0.09	0.19
Markets and cellars	.....	0.150	0.150	.....	.....	.....
Greenhouses	.....	0.160	0.160	.....	0.08	0.08
Miscellaneous	0.314	.....	0.314	0.27	0.28	0.55
Totals	9.268	16.080	25.348	22.60	7.67	30.27
DOMESTIC USES.						
Apartment hotels	0.047	5.850	5.897	1.72	12.34	14.06
Dwelling houses	.....	50.000	50.000	.....	43.90	43.90
Stables	.....	1.500	1.500	.....	1.38	1.38
Hand hose	.....	1.250	1.250	.....	2.25	2.25
Club houses	.....	0.040	0.040	0.18	0.07	0.25
Churches	.....	0.250	0.250	.....	0.18	0.18
Miscellaneous	.....	.....	.....	.....	0.22	0.22
Totals	0.047	* 58.890	58.937	1.90	* 60.34	62.24
PUBLIC USES.						
Hospitals	.....	0.200	0.200	0.30	0.21	0.51
Schools	0.505	0.400	0.905	0.30	0.12	0.42
City, State and Government buildings	.....	0.400	0.400	0.83	0.52	1.35
Urinals, fountains, etc	.....	.....	.....	.....	0.14	0.14
Miscellaneous	.....	0.500	0.500	.....	.....	.....
Totals	0.505	1.500	2.005	1.43	0.99	2.42

* The quantity wasted is included in the unmetered consumption.

Quantity Used for Mechanical, Trade and Manufacturing Purposes.—The quantity of water required for mechanical, trade and manufacturing purposes varies very largely in different communities. In some cities and towns there is very little manufacturing and almost the en-

tire consumption is for domestic use; in other places the domestic consumption is less than the quantity used for manufacturing purposes. Even in manufacturing cities conditions often exist which affect the demand for manufacturing purposes upon the public water supply Fall River is a manufacturing city, but most of the mills obtain a supply of water from the river, and the total amount used in the city for manufacturing purposes is but 2 galls. per inhabitant. On the other hand, where the manufacturers are obliged to take their supply from the public works, the use for manufacturing and trade purposes is from 20 to 30 galls. per inhabitant.

The present consumption in Boston for these purposes is about 30 galls. per inhabitant, and as most of this water is supplied through meters, the quantity used for different purposes can be determined. Table No. 3 shows the consumption in gallons per capita for various purposes from the Cochituate works in Boston in 1880 and also in 1892. The quantity used and paid for by schedule rates has been estimated by dividing the total amount received in proportion to the amount received for different purposes. This method gives results which are fairly accurate, and as the proportion of unmetered water used for manufacturing and trade purposes is small, the quantities used for the purposes enumerated in the table are thought to be nearly correct.

The use of water for mechanical and trade purposes in Boston is increasing at a much more rapid rate than the population, and the author sees no reason why the conditions existing in Boston should not exist in other cities. A very forcible illustration of this fact is given by the following statement showing the consumption per inhabitant for six of the more important mechanical and manufacturing uses in 1880 and 1892. All of the water used by these classes of takers is metered.

Gallons per Capita.	1880.	1892.
Steam railroads	1.14	2.26
Sugar refineries	0.81	1.70
Gas works	0.32	0.75
Electric light and power	.....	0.69
Breweries	0.56	0.89
Elevators	1.03	2.95
Totals	3.86	9.24

The daily quantity used in 1880 for the above purposes was 1 242 900 galls., and in 1892 it was 3 973 200 galls., a difference of

2 731 000 galls., or more than 20% of the total increase in the consumption of the works.

Quantity Used for Public Purposes.—Public purposes include those for public buildings, hospitals, institutions, schools, street sprinkling, flushing sewers, ornamental and drinking fountains, fires, etc. The quantity of water used for these purposes varies to a great extent in different cities, on account of the difference in the methods of supply. In some cases no charge is made for water used for public purposes, while in others the water is supplied through meters and the water department is paid for all water used. When no charge is made the consumption is apt to be excessive. The following examples illustrate this point: In Detroit one hospital containing 150 persons used 625 galls. per capita; another, containing 135 persons, used 548 galls. per capita. A school consumed 2 112 000 galls. in one month, but on charging by meter measurement the consumption was reduced to 435 000 galls.

In Boston many of the public buildings are metered, and the quantity used for public purposes is more nearly the quantity actually needed. The metered consumption for public buildings, schools and hospitals in 1892 was 1.5 galls., and the unmetered quantity is estimated at 0.8 gall., making 2.3 galls. per capita used for these purposes. A careful study of the quantity required for different public uses, based upon such information as the author has been able to obtain, gives the following requirements for the different purposes:

	Gallons.
Public buildings, schools and hospitals	2.30
Street sprinkling	1.00
Flushing sewers, public urinals	.10
Ornamental and drinking fountains	.25
Fires	.10
Total for public purposes	3.75

Probably 4 or 5 galls. per capita should cover all the requirements for public purposes.

From a study of the preceding facts the author draws the following conclusions in regard to the actual requirements of different communities: The quantity needed for domestic use is not more than 30

galls. per inhabitant, and in communities where the number of water fixtures is small in proportion to the population supplied, a smaller quantity will answer all requirements. For business, mechanical and manufacturing use, the amount per capita will differ very largely in different cities, and for various reasons. It is not probable, however, that the actual requirement at present exceeds 40 galls. per capita in any of our large cities.

The quantity needed for public use is not more than 5 galls, making a total of 75 galls. as the maximum quantity needed for actual use, without any allowance for waste.

Quantity Wasted.—If the statements which have been made as to the actual amounts required for domestic use, for manufacturing, mechanical and trade purposes, and for public uses are correct, it is evident that a very large proportion of the total consumption of most of the large cities and towns must be wasted, and in the quantity wasted the author does not include water which is lavishly used, but only that which is either negligently or wilfully permitted to escape without doing any useful service.

Without doubt, the local conditions affect to some considerable degree the per capita consumption for trade, mechanical and public purposes, but making liberal allowance for these conditions, the difference between 75 galls., which should amply supply the legitimate demands of a large city like Boston, and the quantity now used, as given in Table No. 1, shows that the amount wasted in many cities must be more than that used.

There are a number of ways by which the existence and amount of the waste can be quite accurately determined, one of which is by the use of the Deacon waste water meter. These meters have been in use in Boston since 1880, where they were introduced by J. P. Davis, M. Am. Soc. C. E., then city engineer. This meter is placed upon the main supply of a district of from 2 000 to 3 000 persons, and furnishes a continuous record of the rate of consumption in that district. The records of these meters show conclusively that there is an enormous consumption of water during the night, when the legitimate use should be small. In 1883, when these meters were first placed in general use, the average daily consumption in a residential district of 34 800 persons was 69.8 galls. per capita, and between the hours of 1 and 4 A. M., when the legitimate use should be the least, the consump-

tion in the same district was at the rate of 53.2 galls. per head per day. The minimum rate was nearly 80% of the average for the entire day.

During the week ending August 20th, 1893, observations were made to determine the rates of consumption for different portions of the 24 hours from the Mystic works, which supply a population of about 117 000. The results were as follows:

RATE PER HEAD PER DAY.

Time.	Gallons.
1 A.M. to 4 A.M.	40.8
4 " " 7 "	58.6
7 " "10 "	103.8
10 " " 1 P.M.	93.0
1 P.M. " 4 "	93.2
4 " " 7 "	79.5
7 " "10 "	61.9
10 " " 1 A.M.	52.9
Average	73.6

In this case the minimum rate was about 60% of the average and 40% of the maximum, and it is probable that at least 30 galls. per day were wasted.

If there is shown to be a waste of 30 galls. per capita where the total daily consumption is but 74 galls., what must be the condition of affairs in some of the large cities where the consumption is from 125 to 250 galls. per inhabitant? In Buffalo the daily average consumption for the year 1894 was 72 270 000 galls. or 252 galls. per inhabitant. L. H. Knapp, M. Am. Soc. C. E., the engineer of the Buffalo works, states that 70% of the water which they pump is estimated to run to waste, and that it is hard to tell where they will land or how this enormous use of water is to be prevented. The people are not in favor of meters. They have reached the capacity of the works, both as to tunnels, engines and pipes. The additional cost of pumping in Buffalo due to this waste, to say nothing of the increased interest and maintenance account, is from $75 000 to $100 000 per annum. In Chicago, Cleveland, Philadelphia and Detroit, the consumption is about 150 galls., of which probably one-half is wasted.

This waste can be attributed to the following causes: 1st, defective plumbing; 2d, defective street mains and services; 3d, waste to prevent freezing of services; 4th, wilful waste.

Firs'. Defective Plumbing.—In cities where meters are not generally used, defective house plumbing is the cause of the greater portion of the waste of water. The general use of all the modern plumbing conveniences, even in the cheaper class of houses, has become the custom, and has resulted in the manufacture and sale of a cheap class of water fixtures which are the cause of a very large proportion of the waste. From 10 to 15% of the premises examined in Boston are found to have defective fixtures, and of 12 609 defective fixtures reported in 1893, 7 314 were ball cocks. The tank ball cock is without doubt the source of the greater part of the waste from defective plumbing. Unseen and unnoticed a constant and oftentimes large stream runs silently down the overflow pipe to the sewer, and as the water bill is not increased, the property-owner finds it cheaper to let it run than to call in the plumber, the sight of whose bills he fears more than the sound of running water or the complaints of his tenants.

Second. Defective Mains and Services.—From a careful study of the question the author is of the opinion that the waste from the street mains and services is much larger than is generally supposed. It is often said that no leak of any magnitude is likely to occur without showing on the surface of the ground, but broken 4-in. and 6-in. pipes and service pipes running 1 000 galls. per hour have been discovered in Boston which gave no indication at the surface, and which had evidently been wasting water for years. Only a short time ago one of the waste water meters showed an excessive consumption in a short street supplied by a 6-in. main, and a careful investigation disclosed the fact that the main was broken entirely off and the water was escaping unseen into the sewer at the rate of 100 000 galls. in 24 hours.

Third. Waste to Prevent Freezing of Services.—This cause of waste, while not continuous throughout the year, is very large during seasons of extreme cold. The average daily consumption of the Cochituate and Mystic works for the months of November, 1892, and March, 1893, was 51 924 600 galls., while for the intervening winter months it was 60 149 600 galls. The difference of 8 225 000 galls. per day, equivalent to 3 380 000 galls. per day or 6 galls. per capita for the entire year, may be properly charged to cold weather waste.

Fourth. Wilful Waste.—The great cause of wilful waste is the deliberate fastening open of water-closets, thus permitting a constant flow of water for the purpose of cleansing the drains. The desired

result is seldom if ever accomplished, but the ignorant water-taker cannot be convinced of the futility of the plan, and the department suffers in consequence. An example of the wilful use or misuse of water has been brought to the author's notice where a constant stream of water flowing through the kitchen sink was made to answer the purpose of a refrigerator.

Prevention of Waste.—There is no doubt that the most efficient means of preventing waste of water on the premises of the water-takers is the universal use of water meters, for if every water-taker is obliged to pay for all the water entering his premises whether used or wasted, the quantity wasted is very sure to be reduced to a minimum.

The argument has been advanced that the use of meters tends to reduce the consumption of water for sanitary purposes below a point conducive to public health, but this argument has little foundation in fact. The great cause of waste of water is the continual small trickling streams which are of no practical benefit in cleansing drains. The introduction of meters has always been followed by a reduction in consumption, and in the cities and towns where their use has been adopted with the construction of the works, the quantity required per capita is universally very low.

The consumption in the following cities shows the effect of this method of waste prevention:

	Consumers.	Gallons per consumer.	Percentage of services metered.	Metered consumption. Gallons per consumer.
Fall River	85 576	28.5	80.	....
Woonsocket	20 000	26.1	85.2	....
Yonkers—1894	31 000	85.	99.4	52.2
Wellesley—1894	2 933	63.	91.	27.4
Newton—1894	28 500	57.	76.	29.2

By the adoption of a minimum rate which provides an ample allowance for all domestic purposes, the objection to the use of meters on sanitary grounds is obviated. In some cities where the citizens have become accustomed to the lavish and wasteful use of water, and where the mistaken idea is prevalent that water should be as free as the air, the opposition of public opinion will not sanction the general introduction of meters. The people will authorize the expenditure of millions for new supplies of water, larger mains and additional pumping ma-

chinery, but they will strenuously oppose the introduction of meters. In these places much can be done by a thorough and constant house-to-house inspection.

In the author's opinion, next to the general use of meters, the most efficient method of preventing waste is by house-to-house inspection aided by the Deacon waste-water meter. This system is largely used in England, but Boston is the only city of the United States where it has been adopted.* The Deacon waste water meter is the invention of Mr. G. F. Deacon, and was first used in Liverpool about 20 years ago. A trial of the meter in Boston in 1880 gave such satisfactory results that the system was adopted and has been in constant use since 1883. As the construction and operation of this meter is entirely different from the ordinary recording meter, the following description is given:

The cast-iron body of the meter contains a hollow, cone-shaped chamber of brass (see Fig. 1). Suspended in this chamber C is a composition disc D of the same diameter as the upper end of the cone. The fine wire by which the disc is suspended passes through a small hole in the top of the chamber over the pulley R, and is attached to a counter-weight W. When the water in the pipe is at rest the disc is held at the top of the cone by the counter-weight, but when water is drawn through the meter the disc is pressed downward, its position depending upon the quantity of water passing through the meter.

By means of a pencil attached to the wire, the motion of the disc is recorded upon the drum E, revolved by clockwork once in 24 hours. The meter does not, like the ordinary house meter, record the total quantity which has passed between any two observations, but it records upon a diagram the rate of flow at each and every instant. It is thus possible to ascertain the rate of consumption during the night when the legitimate use of water is very small, and determine the amount of water wasted. The meters are placed under the sidewalk upon a by-pass leading from the main, so arranged that by closing the valves on the street mains all of the water used in the section to be tested is drawn through the meter.

The meters in use in Boston are 6 ins. in size, and have a registering capacity of 25 000 galls. per hour. A population of from 3 000 to 6 000 can be supplied at one time through the meter, and the arrange-

* A few meters have been used in Philadelphia for experimental purposes, but the system has not been adopted for general use.

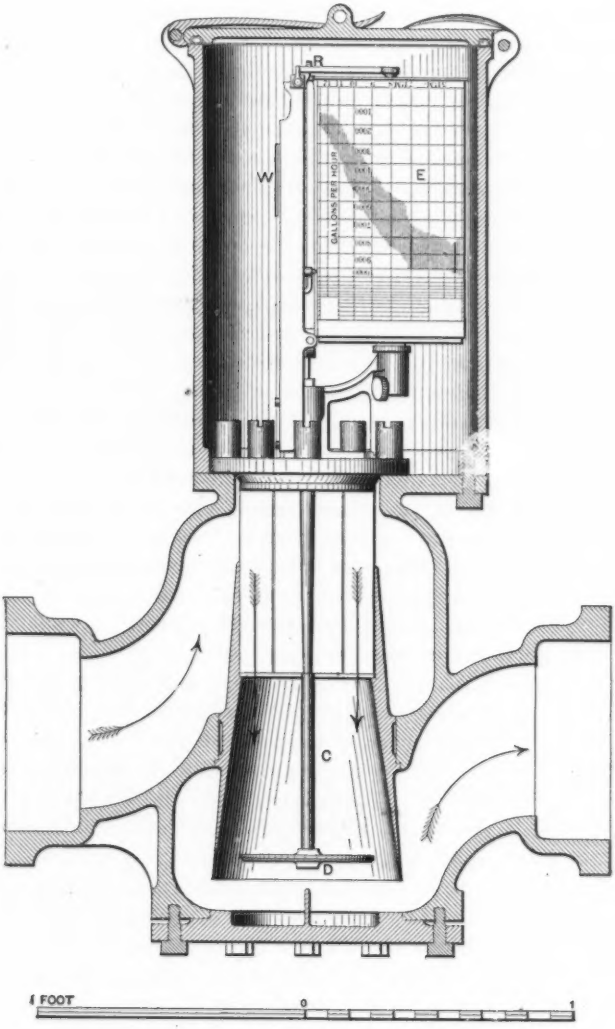

FIG. 1.

ment of the meters and pipe system is such that each meter is used to supply two or more sections. The number of meters now in use is 83, supplying a population of about 420 000.

The method of detecting and preventing waste by this system is as follows: The valves on the street mains are closed, so that all the water in the section to be tested is drawn through the meter. One or two diagrams are obtained showing the rate of consumption, after which the night inspection is begun. The ordinary iron wrench used to let on or shut off the house water supply is applied by the inspector to the sidewalk stop-cock, and by placing his ear to the wrench he can determine whether any water is passing through the service. Note is made of all premises where there are indications of waste, and a complete examination is made by a day inspector to locate the cause of the waste. Notices are then issued to the owners or occupants of the premises, and all defective fixtures are repaired.

One important advantage derived from the use of these meters is that the work of inspection is done where most needed. The meter records determine the streets where the waste is taking place, and the work of the inspector can be concentrated where the greatest saving can be made. Another benefit is the detection of waste from the street mains and services. Neither the use of meters nor the ordinary system of house-to-house inspection will prevent the waste from this cause, and that it is much larger than is generally supposed, the following facts will serve to illustrate.

In the city of Yonkers in 1894, 32 000 consumers were supplied with water through 3 504 services, on which there were 3 482 meters. The daily average quantity pumped was 2 623 760 galls., or 85 galls. per consumer, while the total quantity registered by the meters was 52.3 galls. per consumer; of the remainder, 32.7 galls. per consumer or 1 010 000 galls. per day, a small portion was used for public purposes, but the great proportion is unaccounted for.

In Milton, Mass., all water used in the town is measured by a meter on the supply main, and every service pipe is provided with a meter. The works are but four years old, have 18 miles of cast-iron mains, 376 services supplying about 2 300 persons, and with the exception of water used for flushing mains, street sprinkling, street construction and for fires, all of the water used is measured by meters on the service pipes. The daily average amount registered by the meter on

the supply main in 1893 was 128 529 galls., while the total recorded by the service meters was 65 842 galls. Allowing 2 000 galls. per day for blowing off pipes and fires, there remains 62 687 galls., or nearly 50% of the total consumption which is unaccounted for. In Newton and Fall River., Mass., and Woonsocket, R. I., similar results are shown.

In the city of Newton all services, with the exception of houses having a single faucet, are metered ; and yet, making a liberal allowance for the amount used by the unmetered takers, the quantity of water delivered into the premises of the water-takers during the year 1892 was but little more than one-half of the total quantity pumped. Of a daily average consumption of 1 288 000 galls., 595 600 galls. were used for public purposes or wasted from the street mains or services, or passed through the meters without being recorded.

In the city of Fall River during 1892, 2 217 370 galls. per day, equivalent to 27.24 galls. per capita, were pumped into the mains ; and 1 274 500 galls., or 15.66 galls. per capita were sold ; leaving 942 870 galls., or 11.58 galls. per inhabitant. A small portion of this was used in city buildings and for other public purposes, but at least 10 galls. per capita, or 814 000 galls. per day, more than one-third of the total consumption, cannot be accounted for.

In Woonsocket, R. I., all but a very few of the services are metered, and those few are provided with self-closing faucets and have no hose connections. The quantities recorded by the meters and the amounts pumped during the year 1893 are as follows:

	Pumped.	Recorded by meters.	Percentage.
December 1st to March 1st	46 662 321	21 233 500	45.5
March 1st to June 1st	45 763 500	26 995 684	58.9
June 1st to September 1st	61 589 227	31 943 211	51.8
September 1st to December 1st	50 193 139	26 802 669	53.4
Total for year	204 208 187	106 975 064	52.4
Estimated quantity used for street watering, fountains, etc		25 000 000	
Quantity used by takers paying schedule rates		10 000 000	
Total	204 208 187	141 975 064	69.5

In the calculation of the quantity pumped, an allowance of 5% has been made for the slip of the pumps. Notwithstanding the fact

that more than 80% of the taps are metered, the records show that 62 000 000 galls. per annum, or more than 30% of the quantity pumped, is wasted from the mains and services. These great differences can only be attributed to errors in the quantities registered or to waste and leakage from the street mains and service pipes. It does not seem probable that the loss due to the slip of the pumps and the loss in registration of the meters is more than 20% of the quantity registered by the pumps, in which case there seems to be conclusive evidence that the leakage from the mains is an important factor, and that the use of recording meters will not prevent all waste of water.

The records of the Deacon meters in Boston show conclusively that a very large proportion of the water is wasted. In some of the residential districts the rate of consumption between the hours of 1 to 4 A. M. is from 50 to 100 galls. per capita per day.

Proper Allowance per Capita.—In estimating the quantity to be provided for future years, consideration should be given to the probable legitimate increase in the use of water. Although the greater part of the enormous consumption in some American cities is wasted, there has nevertheless been a great increase in the legitimate consumption during the past 40 years, and without doubt the demands for water will continue to increase in the years to come.

One cause of the increased consumption of water is found in the great increase in the number of water fixtures. Table No. 4 illustrates this growth in Boston.

The proportion of fixtures per capita was nearly twice as large in 1890 as in 1870. Although it is not to be expected that a person will double the use of water because he has twice as many opportunities of drawing it, yet increased use will surely follow from the increase in the number of fixtures.

Another cause of increased consumption is increased pressure in the mains and services. The constant tendency towards increased height of buildings creates a continued demand for increased pressure in the supply mains, and with a large pressure there is more lavish use of water and a greater waste by leakage.

It has been previously stated that 75 galls. per capita is at present an ample allowance for actual uses in a large city. To this must be added an allowance for unavoidable waste and future growth.

The experience of the author leads him to be of the opinion that

it is not practicable to reduce the waste below 15 galls. per capita in our large cities, and that it cannot be maintained at that figure except by the universal use of water meters, aided by Deacon meters or some

TABLE No. 4.

NUMBER OF WATER FIXTURES IN USE AND FIXTURES PER CAPITA, ETC., ON COCHITUATE WORKS, FROM 1870 TO 1892.

Name of fixture.	1870.	Percentage increase.	1880.	Percentage increase.	1890.	Percentage increase.	1892.
Taps	5 893	56.6	9 228	61.7	14 922	12.0	16 706
Sinks	53 010	59.4	84 498	39.7	118 066	6.0	125 151
Bowls	23 961	92.5	46 116	39.8	64 462	6.2	68 448
Bathtubs	8 892	93.8	17 230	85.2	31 914	17.5	37 495
Water-closets	25 050	107.7	52 030	75.4	91 280	12.5	102 687
Urinals	2 447	65.1	4 041	20.7	4 879	—2.6	4 754
Washtubs	9 615	99.1	19 139	126.7	43 389	23.0	53 360
Private hydrants	547	—63.9	197	—81.7	36	—50.0	18
Slop hoppers	723	32.2	956	56.2	1 493	—4.1	1 432
Foot baths	73	90.4	139	101.4	280	—7.1	260
Hydraulic rams	13	—100.0	.....	.....	.....	.....	.....
Totals	130 234	79.3	233 574	58.7	370 721	10.7	410 311
Total population	250 500	31.7	330 000	24.4	410 600	4.8	430 200
Daily average consumption	16 257 700	72.2	28 000 000	21.0	33 871 700	22.0	41 312 400
Fixtures per capita	0.520	36.2	0.708	27.5	0.903	5.6	0.954
Consumption per capita	64.9	31.0	85.0	—2.9	82.5	16.4	96.0
Consumption per fixture	124.8	—3.9	119.9	—23.8	91.4	10.5	101.0

similar device for detecting leaks in the street mains. In cities where water meters are not generally used, the quantity wasted will be from 20 to 100 galls. per capita, as the inspection of mains and house fixtures is more or less rigid.

DISCUSSION.

Mr. FitzGerald. DESMOND FITZGERALD, M. Am. Soc. C. E.—That meters protect the consumer as well as the city against unnecessary expenditures was shown by the speaker's experience. About three years ago, one was placed in his house, and although he did not caution the servants or any of the family against wasting water, there has been a reduction of 30% to 40% in the water bills since that time.

Mr. Rice. L. FREDERICK RICE, M. Am. Soc. C. E.—The speaker's experience had been similar to that of Mr. FitzGerald. Under the old system of rating, his water bills ran from $20 to $25 a year. Eleven years ago he put in a meter and since then no bill has exceeded $6 a year. Reference to the record shows the meter reading to have been 572 on June 2d, 1883, and 41 644 on June 3d, 1895; a total consumption of 41 072 cu. ft., or 307 240 galls. in 12 years. The total cost, at 2 cents per 100 galls., was $61 45, or an average of $5 12 per year.

Mr. Darrach. CHARLES G. DARRACH, M. Am. Soc. C. E.—The figures in the paper concerning the daily consumption of water in Philadelphia, Pa., 150 galls. per capita, are open to question, as the municipal reports for the last few years rate the pumps much higher than their probable capacity. Tests of two of them showed their capacity to be 20% lower than stated in the municipal reports. A great increase in the consumption of water in the city occurred shortly after some large new reservoirs were brought into service, and the speaker believed that there is considerable waste of water through the bottoms and walls of the reservoirs, and not so much along the pipe lines and in the buildings as the recorded total consumption indicates.

Mr. Dunham. H. F. DUNHAM, M. Am. Soc. C. E.—The speaker had found in making tests of entire pipe systems where the mains ranged from 16 to 4 ins. in diameter and a pressure of 50 lbs. per square inch was maintained, that the quantity of water escaping did not exceed 1 gall. per minute per mile of street main. These tests were made when the pipe systems were new and before the introduction of service pipes. They did not include such breaks as would immediately appear on the surface, but did include some leaks from porous castings, faulty joints and imperfectly packed gates that were noticed subsequently. The quantity was determined by plunger displacement. It is one disadvantage of a gravity supply that the quantity of water discharged by a leak of considerable proportions cannot be ascertained so readily or the time of its commencement recorded so clearly as it must be in a well-managed pumping station.

JOHN THOMSON, M. Am. Soc. C. E.—In a general way the speaker was somewhat familiar with the statistical data contained in the paper, but their arrangement to denote the different classes of use and waste not only seemed to be novel, but, in his opinion, is highly valuable. Thus, as shown in Table No. 2, it seemed surprising that portions of the domestic service in Boston, Newton, Fall River and Worcester, and the entire supply of Yonkers, under the relatively free direct service through meters, should be practically no greater than in the instances cited from two districts in London; and this is especially remarkable should it appear that the London districts were partially or wholly under intermittent supply. If the author can answer as to this, and should it be shown, as the speaker assumed, that the London districts were wholly or partially under intermittent supply, then it is about as conclusive evidence as need be desired that the domestic use of water, when paid for according to the quantity drawn, neither leads to restriction nor to lavishness. Mr. Thomson.

Although averages are sometimes deceiving and uncertain, another interesting deduction might be made from this table by dividing the sum of the several per capita consumptions by the twenty-two different conditions of service cited, this giving an average daily use of 24.5 galls. to each person.

As to the quantity of water unaccounted for, as cited on pages 200 and 201, the author's data furnish material for mental exercise, and it is interesting, as well as suggestive, in the instance of Yonkers, to divide the per diem loss of 1 010 000 galls. by the entire number of services, 3 504, thus finding that a leak in each, or a loss in registration by each meter, if all were metered, of 288.7 galls. per day (about 12 galls. per hour) would account for the quantity lost. Now, although the water pressure in Yonkers is higher than that of the average water-works service, ranging from 75 to 125 lbs. to the square inch, it is surprising to find that the 368 650 galls. of water unaccounted for could be delivered in one year through 3 504 thin diaphragms, having comparatively sharp-edged orifices of but 0.03-in. diameter. These figures seem somewhat opposed to some of the speaker's earlier reasoning on this subject;* but the premises have changed somewhat, and in any event this should not stand in the path of a pressing argument. Nevertheless, he was not ready to admit that there is any necessity for attempting to measure water, through meters, by the drop. In Woonsocket, R. I., where 62 000 000 galls., or more than 30% of the quantity pumped, is unaccounted for annually, this amount is equivalent to but about 110 galls. per service daily, less than half the amount at Yonkers, N. Y.

The author has referred in general terms to the different causes of

* "Is the Game Worth the Candle?" *Journal* of the New England Water-Works Association, Vol. VIII, No. 2.

Mr. Thomson. waste, and the speaker, of course, most promptly agreed with the leading conclusion as to "the most efficient means of preventing waste of water," but stated that in this connection it may be of interest to cite one definite instance where the experience was dearly bought.

About three years ago many of the clubs and theaters of New York City were notified by the Department of Public Works to apply meters, among the number being the Engineers' Club. No protest was made and a meter was applied. Several months ago the first bill was rendered, covering about 16 months, showing a consumption of 2 207 250 galls., the amount due being $294 30, or a little over $18 per month. The aforesaid quantity averages a trifle over 3 galls. per minute for the entire period of about 500 days. Every legitimate effort was made to cut at least one figure from the inspector's reading, but in this even the engineers of the department, who are also members of the club, were failures; the bill stood and the club's treasurer begrudgingly paid it. Upon investigation, it was found that a stream had been running constantly, night and day, first to a tank on the roof and thence through the overflow to the sewer. Since that experience the constant flow has been stopped, and the club is now paying about $6 per month instead of $18. A few of such cases, in one system, would seem to indicate that measurement by the drop, while laudable, is not necessary. This query seriously arises: In a case, say, of water scarcity, would not such useless wastes, even if paid for, be bordering upon contributory criminality?

In conclusion, reference was made to the assertion on page 195, which, however, was presumed to be a quotation, referring to the city of Buffalo, that "the people are not in favor of meters," by this conveying the idea that *per contra* the people are in favor of being taxed to increase the present enormous wastage. To this statement, the speaker took direct exception, for he believed that in every such case, if the matter were properly presented to and were directly decided by the citizen taxpayers, they would simply act upon business principles. Would a private water company act otherwise than as here intimated? Then why should a mutual company make it possible for certain of its beneficiaries to take advantage of the others? That such a question should so frequently be up, as if for argument on the merits, is indeed remarkable in a way. And yet there is ground for the opposition. Thus in a report just published by the superintendent of the Richmond, Va., Water-Works, he says: "I do not exaggerate in saying 95% of those paying for water by meter measurement have saved largely in their water bills, and are pleased." But in the conclusion of his report, this significant statement appears: "I have said before, however, that our City Council is opposed to the meter system." And there's the rub betimes; for the beneficent glory of politics, and even the exercise of the engineering function, may be thought by some to be the

Mr. Thomson.

better displayed (to the voting populace) by the building of great public works than in the conserving of that they now have. Between politics and engineering conservatism on the one hand, and the exceedingly difficult practical requirements on the other hand, the growth of the meter service has been tedious, a life that has resulted simply as a "survival of the fittest." But, as Tyndall has said, "the plant may be all the hardier for the buffetings it has undergone." Thus, less than a decade ago, the total number of meters made per year by all the manufacturers of the United States did not exceed 15 000, whereas the output for the year 1895 will not be far from 50 000; and the relation of these figures, say as 1.5 : 5, may be taken to fairly represent either the growing necessity for the employment of water meters or the increase of sentiment favorable to their adoption.

Mr. Croes.

J. J. R. Croes, M. Am. Soc. C. E.—In the city of Yonkers, N. Y., to which allusion has been made in the paper, there is a dwelling house occupied by a family of five adults, in which all the rain water that falls upon the roof is collected in a tank in the attic and a cistern above ground, from which water is drawn through a filter of gravel and charcoal. The pipes are connected with the city mains, and when the supply in the tank runs low, the city water is admitted through a meter. Assuming all the rainfall to be collected, the consumption of water in this dwelling for five years past, as derived from the quarterly reading of the meter and the records of rainfall in Yonkers, has been as shown on the following table:

Three months ending:	Rainfall.		Metered.	Cubic Feet.
	Inches.	Cubic feet.	Cubic feet.	Total.
August 31st, 1890	13.15	1 460	356	1 816
November 30th, 1890	11.21	1 244	598	1 842
February 28th, 1891	*17.12	1 900	453	3 353
May 31st, 1891	9.81	1 089	703	1 792
August 31st, 1891	6.63	736	1 464	2 200
November 30th, 1891	8.07	896	1 133	2 039
February 29th, 1892	11.39	1 264	765	2 059
May 31st, 1892	8.65	961	1 173	2 134
August 31st, 1892	12.51	1 389	1 168	2 677
November 30th, 1892	9.31	1 033	1 253	2 286
February 28th, 1893	7.50	827	1 179	2 006
May 31st, 1893	*14.12	1 567	1 235	2 802
August 31st, 1893	*12.57	1 396	1 777	3 173
November 30th, 1893	12.37	1 374	1 290	2 664
February 28th, 1894	8.50	944	1 624	2 568
May 31st, 1894	8.47	941	1 502	2 443
August 31st, 1894	4.54	504	1 820	2 324
November 30th, 1894	*22.54	2 502	1 412	3 914
February 28th, 1895	10.22	1 134	1 477	2 611
May 31st, 1895	5.95	661	1 819	2 480
Mean	10.73	1 191	1 210	2 459

Mr. Croes. The mean daily consumption for 1 826 days was 26.94 cu ft., or 202 galls. Omitting the four periods of excessive rainfall, marked in the table with an asterisk, when a portion of the rainfall was wasted by overflow from the cistern, the mean daily consumption for 1 461 days was 24.61 cu. ft. or 184.5 galls., being 36.9 galls. per head of occupants of house. The fixtures in the house are kitchen range and boiler and sink, washtubs, three wash basins, bathtub, and two water-closets, and water is used freely.

Water is not used for lawn sprinkling nor for street or pavement washing, but in summer some water is used for hand sprinkling of flower beds.

Mr. Kuichling. E. KUICHLING, M. Am. Soc. C. E.—The speaker called attention to the great value of the data presented by the author, and was much interested in the recommendation that all of the water drawn from the mains for private consumption should be metered, inasmuch as he had advocated the same measure for many years past, and was thoroughly convinced that it was the only rational method of controlling waste. He also referred to the large variation in consumption of water which occurs in the different seasons of the year in cities where meters are not extensively used, and pointed out that these variations were particularly important in determining, on the one hand, the necessary storage volume that should be available in the reservoirs of gravity works, and on the other hand, the reserve engine capacity needed in pumping works. For such purposes, data of consumption and waste derived from averages are of little value, since the governing figures are necessarily the maximum quantities which occur during comparatively short periods of time, such as a few days, or a week.

In illustration of this point, the speaker referred to the author's estimate that about 6 galls. of water per capita are wasted daily in Boston throughout the entire year, to prevent the freezing of the service pipes in buildings. From the paper, however, it is seen that the difference in consumption between the winter months and the preceding and following months of November and March amounted on the average to 8 225 000 galls. per day, for the period from October 31st, 1892, to April 1st, 1893. Assuming the population at 430 000, as given in Table No. 3, the average waste during the winter months is thus found to be 19.1 galls. per capita per day, or more than three times the average distributed through the entire year. It is to be regretted that the author did not give the figures for the maximum loss from the cause mentioned, as it is very probable that a much larger proportion would have been disclosed. In the case of several small cities, the waste during very cold periods has actually amounted to three or four times the ordinary daily consumption in the spring and fall; and in one city of about 160 000 inhabitants, the consumption for 10 days

during and after a severe blizzard last winter was at more than double the rate prevailing in May and November. Examples of this kind are of importance in connection with other data relating to the use and waste of water from public supplies, as they justify an engineer in making a liberal estimate for either reserve engine power or storage capacity in the design of new works. Mr. Kuichling.

The speaker also called attention to the particular desirability of a general meter system in the case of water-works which are supplied by a gravity conduit, and to the fact that where meters are extensively used the weekly and monthly consumption of water is very much more uniform than in places where meters are not used. Data in support of this fact are not frequently met with, owing to the labor involved in classifying the numerous accounts, and the following statistics which were compiled under the speaker's direction in the water department

STATEMENT SHOWING QUANTITY OF WATER PASSED MONTHLY THROUGH 2 645 METERS DURING THE FISCAL YEAR 1891, AND THROUGH 3 014 METERS DURING THE FISCAL YEAR 1893–94, IN THE CITY OF ROCHESTER, N. Y., FOR THE DIFFERENT USES INDICATED:

Month.	Year.	Domestic. Cubic feet.	Commercial Cubic feet.	Manufacturing. Cubic feet.	Total. Cubic feet.
No. of meters		798	1 552	295	2 645
April,	1891	1 671 570	4 047 150	4 055 748	9 774 468
May,	"	1 388 309	3 832 223	3 865 201	9 085 733
June,	"	1 583 679	3 772 401	3 774 190	9 130 270
July,	"	1 427 647	3 746 688	4 245 141	9 419 476
August,	"	1 431 356	4 155 907	4 217 450	9 774 713
September,	"	1 419 741	4 178 238	3 952 164	9 550 143
October,	"	1 481 273	4 142 925	4 088 003	9 712 201
November,	"	1 572 703	3 971 598	4 254 038	9 798 339
December,	"	1 376 652	3 796 175	3 668 970	8 841 797
Averages,	1891	1 483 659	3 957 031	4 013 434	9 454 127
No. of meters		1 093	1 618	303	3 014
June,	1893	1 654 016	4 632 323	4 197 860	10 484 199
July,	"	1 588 105	4 730 581	4 445 094	10 763 780
August,	"	1 600 848	4 327 964	4 444 586	10 373 398
December,	"	1 471 543	4 161 903	3 891 245	9 524 691
January,	"	1 638 259	4 467 307	3 772 614	9 878 180
February	"	1 640 456	4 586 693	3 681 974	9 909 123
Averages for three summer months		1 614 323	4 563 623	4 362 513	10 540 459
Averages for three winter months		1 583 419	4 404 301	3 781 944	9 769 664
Averages for twelve months		1 501 966	4 401 526	4 170 755	10 074 247

of the city of Rochester, N. Y., were submitted. The uses of water in that city were divided into three general classes: 1, domestic consumption, embracing all ordinary uses of water in dwellings, apart-

Mr. Kuichling. ment and tenement houses and boarding houses; 2, commercial consumption, embracing uses of water in hotels, restaurants, saloons, commercial buildings with offices and apartments in upper stories, stores, warehouses, livery stables, barber shops, bath houses, and public and charitable institutions; 3, manufacturing consumption, embracing the use of water in breweries, distilleries, paper mills, flouring mills, railroads, fruit-canning works, bakeries, photographers', confectioners', and printing establishments, and in factories and workshops of all kinds.

An examination of the foregoing statement shows a remarkable uniformity in the monthly consumption of water by the three different classes of consumers, the extreme variation throughout being only about 10 per cent. On the other hand, the rates at which the water is actually used throughout the city under the same conditions of pressure differ widely, according to the season; and this fluctuation in consumption must therefore be due to the very large number of unmetered services. In a gravity system, however, which is taxed to its utmost capacity, the supply is practically uniform, and periods of maximum consumption cannot be tolerated without rendering a water famine imminent, but by the general use of meters it is possible to avert such a calamity by rendering the consumption nearly uniform throughout the year, as shown in the statement.

CORRESPONDENCE.

L. J. Le Conte, M. Am. Soc. C. E.—The rate of consumption of water in the large cities of the United States is a perfect anomaly. The paper is a praiseworthy attempt to give more valuable light on the subject, as to its cause and prevention. The marked difference between the rates in small cities as compared with larger ones at once suggests new demands in large cities which hardly exist in the smaller. The writer was much impressed by the classification of the legitimate daily consumption in Boston, namely, 75 galls. per diem per capita, showing for industrial and mechanical uses, 53%; domestic uses, 40%; and public uses, 7 per cent. This at once calls to mind the importance of modern demands for water by hydraulic elevators and water motors. Both of these devices have now become firmly established as public necessities, and their number is rapidly multiplying every year. They have no equal as extravagant consumers of water, as instanced by the fact that special rates have to be applied to such cases, otherwise the water bill presented at the close of each month would assume truly alarming proportions. Mr. Le Conte.

The author's respect for meters as a preventive of waste in general and wilful waste in particular will be shared by every fair-minded person. They have done and are doing an invaluable service toward establishing and maintaining wise economy. The writer thinks it proper to mention one feature about them which, in all fairness, needs to be studied. He has reference to the ratchet meters, which not only record the passage of water through the meter, but also record pulsations in the water main.

His attention was first called to this in 1885, but he neglected to follow it up. In 1889, at the ninth annual convention of the American Water-Works Association, Mr. James P. Donohue, of Davenport, Ia., called attention to unquestionable proof of the fact which came under his own notice. With the general introduction of elevators and their accompanying pulsations or water-hammer, there is a new element of disturbance entering into the problem which will have to be faced and properly solved by the meter manufacturer. A single elevator affects the record of all such meters within many blocks, which happen to be attached to the same main. It is manifestly unfair to have pulsations in the water main charged to the consumer's account.

As to the proper allowance per capita to adopt in designing new water-works there is plenty of room for difference of opinion. The best data available as a guide are supplied by past experience in the same line. Looking back and comparing preliminary estimates with subsequent results there is truly much to make engineers feel humble.

Mr. Le Conte. There is every reason to believe that the legitimate use of water per capita will increase rapidly in the near future, and consequently the writer does not think it prudent to estimate on new water-works for a large city at a lower rate than 200 galls. per diem per capita.

Mr. Herschel. CLEMENS HERSCHEL, M. Am. Soc. C. E.—The principal lesson to be learned from the paper as to a prevention of waste is the old and repeated one—that keeping accounts is at the foundation of an economical conduct of any business, and that to keep accounts in the water-supply business, the water must be measured, that is, metered. To meter large quantities of water, the paper refers to one meter only, the Deacon waste water meter. It is built ordinarily in four sizes only, 4 in., 6 in., 8 in. and 10 in. diameter of the inlet and outlet pipes, and the design of the meter is such that larger sizes are inconvenient in use or impracticable. The horizontal motion of the water in the inlet pipe is turned in a vertical direction, is passed through a circular thin slot, and is then goose-necked back again into a horizontal direction. As a consequence, it is impracticable to use such a meter with an inlet pipe more than 10 ins. in diameter, as it would make the whole apparatus too cumbersome. There is also the necessity of setting a by-pass, for the slot is liable to clog up, and at any and all times the Deacon meter is a great slaughterer of head. As a meter, the apparatus is doing well, when it measures within 5% of the truth. Indeed, its principal function is not to meter, but to indicate relative flows through the pipe under examination, and to draw a diagram of the relative quantities passing.

The use of a meter on mains of any size and on all the principal pipes of the distribution system of a city is, however, perfectly feasible, and would contribute largely to an economy in the use of water. The writer has many times stood by the side of a black and silent 16-in. or 24-in. pipe carrying wash water to a large manufacturing corporation, and wished there were some way of readily procuring a record of what was going on within those hidden and silent confines of the pipe. In the course of years, that wish has been gratified, by the labors of the writer and of others, until now, if the writer were to lay a distribution system, he would certainly place meter tubes in the line of every size pipe laid, and at frequent intervals; so that a strict account could be kept at any time of the actual distribution of water within districts of any desired extent or limitation.

The meter tubes referred to are those of the Venturi meter, described* in the *Transactions* of this Society, and now forming an article of commerce, both in the United States and abroad. The meter-tubes of this meter are of a length equal to about 10 times their diameter, and their cost is about three times that of an equal length of plain pipe. No by-pass is needed, or has ever been used, to the writer's

* Vol. XVII, 1888, page 228.

knowledge; the head lost is a trifle, not so much as is destroyed by an ordinary check valve. Any size pipe may be fitted with these tubes, from ¼ in. to 240 in. or more; the register, to register total cubic feet passed, or to make a diagram of the rate of flow, or to perform both of these functions simultaneously, is applicable to any size of meter tube and meters the water passing it within ½% of the truth, for any single record reading. This register could readily be used as a portable register, and be connected at will with the selected meter tube by two little pipes conveying pressure, not a stream of water, from the tube to the register. For city street use or for waste water inspection, this would be the proper way to set the whole apparatus; the meter tube set permanently in the line of the street pipe and constructed so as to meter water flowing in either direction whenever there is any possibility of reversed currents in the pipes; the register set temporarily at any convenient place within 100 or 1 000 ft. of the tube, and connected with it as described. Where used simply as a meter and to register total quantities passed, the register is set permanently in some convenient place, not too far from the tube. Many such meters have been doing daily service for the past three years at home and abroad. Mr. Herschel.

It is time that civil engineers recognize in their general practice that a pipe conveying water need no longer be the dead, silent, secretive factor it usually is, or as it has above been described from old-time recollections of the writer's practice, but that the introduction of a Venturi meter tube in the line of a pipe can cause it to speak with accuracy and precision respecting the flow of water within it at any desired time. Were pipes generally thus made to reveal at will the flow of the water within them, and were systematic records of this flow kept in cities, the waste of water, now furthered by the absence of all information on this subject, would materially diminish. Certain it is that the unseemly record of broken 4-in. and 6-in. pipes wasting 1 000 galls. per hour for years without detection would then no longer be possible.

Robert Cartwright, M. Am. Soc. C. E.—The writer read the paper with much interest, and the statistics therein given are a valuable contribution to the profession. He fully agrees with the author in his conclusions, that mainly by the metering of all services can the lavish waste of water be controlled. The writer's connection for a period of some 30 years with the manufacture and distribution of illuminating gas has convinced him of the necessity of placing some restraint upon the prodigality of consumption so prone to the American people, and which has given rise to the trite saying that "any other nation in the world could live well upon the waste of the people of the United States." Mr. Cartwright

No doubt much of the waste of water results from the parsimony of landlords in saving expense by putting in cheap plumbing and materials, and the running of water to prevent freezing, as shown by the paper.

Mr. Cartwright

The periodical inspection of every service the writer regards as very essential for the detection of waste, as no doubt many instances happen without regard to the material or the quality of the plumbing and in unlooked-for ways, as in the facts herein given occurring in the writer's experience. In Rochester, N. Y., all sprinkling of lawns has been prohibited for some years, owing to the water not being available, by reason of lack of facility to convey the water. Last fall a new supply main was completed, and citizens now have the opportunity of using all the water they wish, provided they purchase such meters to register the consumption as are tested and approved by the water officials. Water is supplied at the rate of 14 cents per 1 000 galls. The writer availed himself of this provision, and after due consideration and investigation, naturally selected a disk meter as being the most accurate, simple and economical for his uses. The meter was tested in his presence by the water officials, and found absolutely correct at both maximum and minimum flow.

The writer's residence was built in the fall and winter of 1892, and was equipped with the best plumbing to be had, both in workmanship and materials. The meter was set and put in operation Saturday, May 5th, 1895, at noon. At 10 P. M. that night, the registry was somewhat surprising to the writer, as it indicated a remarkable industry on the part of the meter. Absence from home prevented another inspection until 6 o'clock P. M. on Monday, May 7th. Surprise gave place to disgust when the register showed 476 cu. ft. as having passed in about two and one-half days, and a remedy was sought. The water is supplied by an independent pipe from the street main to a tank holding about 100 galls. in the attic, and fitted with a valve controlled by ball float. An overflow is provided from the tank to the sewer in case of any accident to the float valve. From the bottom of the tank, connection is made with the house system of piping, with a cock just outside the tank. In case of a lack of pressure in the street mains to raise the water to the tank, a by-pass is placed in the cellar, between the independent riser and the house system and fitted with a ¾-in. globe valve. With this arrangement, an approximately constant and reduced head is maintained on the house system, when the by-pass is shut.

An examination of the float valve resulted in putting a new seat on it, although the leak was trifling. When the water was turned on after making the repairs, the tank began filling, although no water was passing the float valve. This proved that water was coming *via* the by-pass, notwithstanding the valve was closed. The cap of the ¾-in. by-pass valve was removed, and showed that the seat had never been put in, and it had evidently been sent from the factory in that condition. Here, then, was the solution of the question. A new seat was put in, and the writer's faith in meters was restored. For over two years the water had been running directly to the sewer, through this

defective valve, and enough had been wasted to have supplied several families in the interim. A night inspection and application of the waterphone would have detected this loss. This is only one instance where the application of a meter divulged the waste, and undoubtedly there are many just such cases existing. The writer views the metering of water as having a moral influence upon the majority of consumers, since when a check is placed upon the consumption of water in the shape of a tell-tale mechanical watchman, the party paying the bill is very apt to count the cost of carelessness or indiscretion, and will prevent a waste that otherwise would not be considered. In fact, the writer believes that a meter case without any works inside, applied to a service, would serve an admirable purpose in reducing waste in many instances. Mr. Cartwright

For years the writer has been convinced that the metering of every water service (the meter to be furnished free to the consumer, as is the case in illuminating gas supply) would cost less in the outlay for meters than the outlay for new conduits, reservoirs and pumps, with their maintenance, to say nothing of the waste of potable water.

A community will vote thousands of dollars to extend its water supply more readily than it will expend hundreds in supplying meters which will curtail and control the waste. No private individual would long carry on the business of pumping and supplying water when no check is placed upon the consumption, and yet municipalities almost universally adopt that plan.

The daily use of water in the writer's family is as follows: The family consists of six adults; the house is fitted with bath, two closets, two wash basins, three stationary wash tubs, beside kitchen and pantry supply, and embraces 19 faucets. The minimum rate of water used is 16 cu. ft. per day, the maximum is 54 cu. ft.; the average for about three months is 34.83 cu. ft. per day, Sundays being the lowest and Mondays (wash day) the highest. This shows an average use of 261 galls. per day for the family, and an average per capita per day of 43.5 galls.

According to the author's statistics, Philadelphia, Pa., uses 150 galls. and Buffalo uses 252 galls. per capita per day, and the question forcibly presents itself, What shall the engineer assume as a reasonable per capita estimate, when planning a water supply? To the writer's mind, the meter offers the only solution of the question, and when every water service is metered, 75 galls. per capita per day would seem an ample provision for a supply.

DANIEL W. MEAD, M. Am. Soc. C. E.—The increase in the per capita consumption of water in most of the cities of the United States is now very rapid and is fast becoming a serious matter. In many cases, it is almost or quite impossible financially for the cities to enlarge their works fast enough to keep up with the extravagant use of Mr. Mead.

Mr. Mead.

water. In the majority of cases, a large amount of the water used is unquestionably wasted, and in many instances much better results would be obtained if the city officials confined their attention to the restriction of waste rather than the enlargement of the works.

In the fall of 1894, the writer was called to examine and report on the enlargement of the water-works system of the city of Rock Island, Ill. This is a city of perhaps 18 000 inhabitants, and draws its supply from the Mississippi River. While having a reasonable number of manufacturing establishments, it has no great manufacturing interests which would consume large quantities of water, and there is no apparent reason for the excessive consumption of water which is taking place.

The following table gives the average daily consumption per capita for each month of each year since 1889, and exhibits the excessive consumption in that city in detail.

TABLE SHOWING CONSUMPTION OF WATER AT ROCK ISLAND, ILL.

YEAR.	Reported and estimated population.	Mean daily consumption. Gallons.	Average daily consumption per capita.* Gallons.	AVERAGE DAILY CONSUMPTION PER CAPITA FOR EACH MONTH.											
				January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1850.....	1 711														
1860.....	5 130														
1870.....	7 890														
1880.....	11 659														
1889.....	13 595	1 935 647	140	....	....	....	157	152	154	153	152	158	153	143	135
1890.....	13 890	1 702 395	121	121	120	109	97	109	116	147	155	146	145	114	116
1891.....	14 180	2 020 372	142	110	112	104	106	133	156	172	176	168	138	144	132
1892.....	14 465	2 105 836	144	134	128	117	118	122	137	150	158	156	150	149	145
1893.....	14 745	2 174 031	146	156	158	145	144	158	158	159	170	162	143	140	129
1894.....	15 020	2 528 509	167†	133	138	136	145	156	184	185	172	....	....	....	....

* Averages from April to April.

† Average from April to September.

To ascertain the rate of consumption for different portions of the 24 hours, observations were taken for two days in September and for the three days, November 30th, December 1st and 2d, 1894. From the half-hourly readings of the pump counters, Fig. 2 was plotted. It will be noticed in the part of the diagram for September, that the minimum rate is almost 73% of the average, and about 56% of the maximum rate, the minimum rate at night being about 1 400 galls. per minute. In November and December the average minimum rate is about 90% of the average rate and about 72% of the maximum rate. While the maximum rate of 2 500 galls. per minute in September has fallen in November and December to 1 600 galls. per minute, a decrease of 900 galls. per minute, the minimum rate at night has decreased only

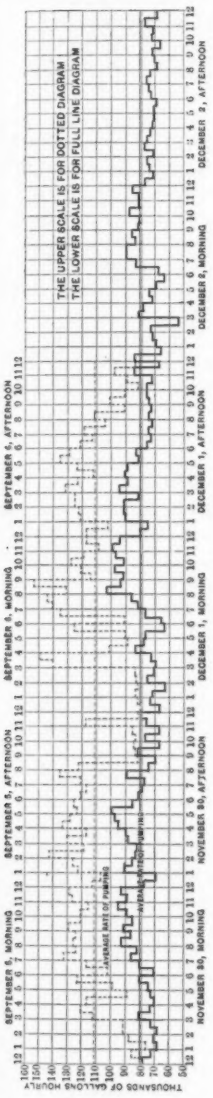
THE UPPER SCALE IS FOR DOTTED DIAGRAM
THE LOWER SCALE IS FOR FULL LINE DIAGRAM
AVERAGE RATE OF PUMPING
THOUSANDS OF GALLONS HOURLY
SEPTEMBER 5, MORNING
SEPTEMBER 5, AFTERNOON
SEPTEMBER 6, MORNING
SEPTEMBER 6, AFTERNOON
NOVEMBER 30, MORNING
NOVEMBER 30, AFTERNOON
DECEMBER 1, MORNING
DECEMBER 1, AFTERNOON
DECEMBER 2, MORNING
DECEMBER 2, AFTERNOON

Fig. 2.

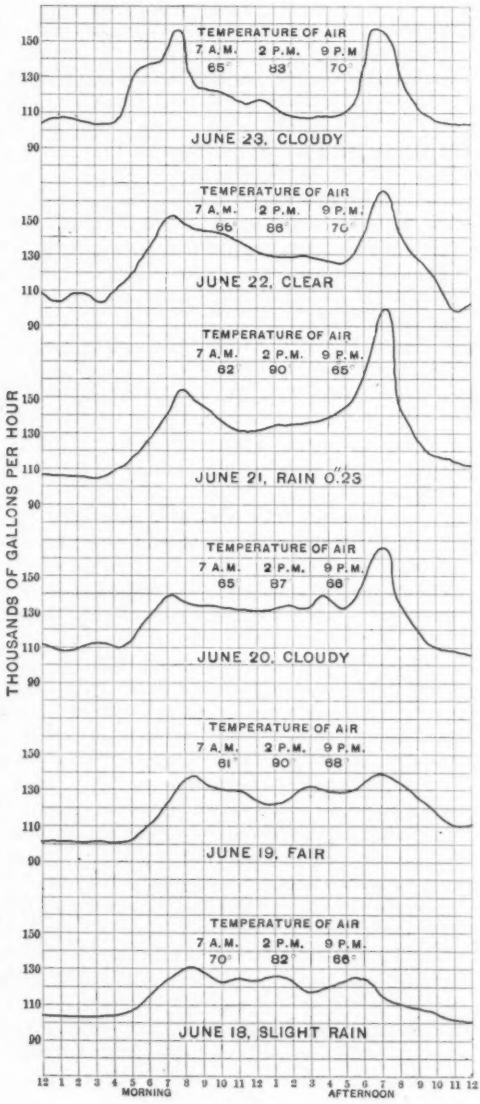
THOUSANDS OF GALLONS PER HOUR
TEMPERATURE OF AIR
7 A.M. 2 P.M. 9 P.M.
65° 83° 70°
JUNE 23, CLOUDY
TEMPERATURE OF AIR
7 A.M. 2 P.M. 9 P.M.
66° 86° 70°
JUNE 22, CLEAR
TEMPERATURE OF AIR
7 A.M. 2 P.M. 9 P.M.
62° 90° 65°
JUNE 21, RAIN 0.″23
TEMPERATURE OF AIR
7 A.M. 2 P.M. 9 P.M.
65° 87° 66°
JUNE 20, CLOUDY
TEMPERATURE OF AIR
7 A.M. 2 P.M. 9 P.M.
61° 90° 68°
JUNE 19, FAIR
TEMPERATURE OF AIR
7 A.M. 2 P.M. 9 P.M.
70° 82° 66°
JUNE 18, SLIGHT RAIN
MORNING
AFTERNOON

Fig. 3.

Mr. Mead. about 80 galls. per minute. There is evidence in the diagram of an excessive waste of water, which, if remedied, would have a marked influence on the relative capacity of the plant. Some of the smaller irregularities in the diagram can probably be accounted for by probable irregularities in the reading of the counter.

Fig. 3 shows the mean curve of the rate of consumption of water at Rockford, Ill., for six days in June, 1895. Rockford is a city of about 30 000 inhabitants, and the average consumption of water is about 90 galls. per capita, considerably less than that of Rock Island. The large consumption of water during the night, when the consumption should be relatively small, would, however, seem to indicate an excessive waste of water. The diagram shows the large consumption during the sprinkling hours and the effect of a higher temperature on the use of water.

Mr. Hazen. ALLEN HAZEN, Esq.—The statistics on page 219 in regard to the consumption of water in 30 cities in Germany and German Switzerland have been taken from the excellent statistical report of the German Society of Gas and Water Experts for the year 1893. This report contains statistical information with regard to 75 water-works, from which the 30 were selected, either because the statistics were more complete than for the others, or because the cities were larger and have greater interest. The quantities are stated in the original report in cubic meters annually for the entire city, and have been reduced to gallons per inhabitant daily by the use of a slide rule. They are thus only approximately exact, although it is believed there are no large errors, because the totals have been checked with the sums of the various parts in each case after reduction.

In addition to the data given in the table, this report contains detailed information in regard to the quantities of water used for the various public purposes in many of the cities, although the quantities of water used for different purposes are often not stated in full, particularly where the total quantity for public purposes is but small.

The water-works themselves require a quantity of water ranging from nothing to over 6 galls., and averaging for 16 cities 0.54 gall. per inhabitant daily. Street sprinkling requires from 0.01 gall. to 1.10 galls., averaging 0.34 gall. for 28 cities. A further quantity of water, ranging from nothing to 1.35 galls., was used for watering parks, and averaged 0.23 gall. for 22 cities. Ornamental fountains required from 0.01 gall. to 3 galls., and in one case 6 galls., averaging 0.66 gall. for 26 cities. Drinking fountains required from 0.01 to 5.23 galls., averaging 0.95 gall. for 21 cities. Flushing and washing gutters required from 0.01 to 0.49 gall., averaging for 7 cities 0.08 gall., and sewer flushing required from 0.01 to 1.52 galls., averaging 0.42 gall. for 17 cities. Public closets required from 0.02 to 1.69 galls., averaging 0.53 gall. for 26 cities. From 0.001 to 0.63 gall. was required for

extinguishing fires, averaging 0.07 gall. for 18 cities, but in only two cases was the quantity above 0.025 gall. Nineteen cities report water used for special purposes not specified, ranging from 0.001 gall. to 4.43 galls., averaging 0.82 gall. The sum of these averages is 4.64 galls., but owing to the incompleteness of the returns, and to the fact that probably many of the cities use no water for some of the purposes, and as zeroes are not included in the average, the result so calculated is considerably higher than the 3.61 galls., which is the average quantity for all public purposes shown in the table. Mr. Hazen.

USE OF WATER IN SOME GERMAN CITIES.—GALLONS PER CAPITA DAILY.

Place.	Population.	Consumption.	Public purposes.	Private, Metered.	Private, Estimated.	Not accounted for.
Altona	156 500	26.70	.....	.....	.....	.....
Barmen	118 500	33.59	1.33	11.30	17.60	3.36
Basel	74 500	34.78	7.47	19.80	0.96	6.55
Berlin	1,606 424	16.37	1.63	14.45	.....	0.29
Bonn	52 000	24.94	0.79	11.40	12.50	0.25
Breslau	335 000	21.71	6.01	15.70	.....	.....
Chemnitz	139 374	11.50	3.35	8.15	.....	.....
Cologne	255 000	45.22	8.92	5.70	30.60	.....
Crefeld	105 712	18.52	0.61	4.71	13.20	.....
Danzig	107 085	26.70	.....	11.30	.....	.....
Dresden	280 200	21.54	1.80	12.39	7.30	0.05
Dusseldorf	155 900	22.10	1.44	10.80	7.65	2.21
Elberfeld	137 000	29.92	7.16	22.75	0.01	.....
Frankfort	186 000	36.26	2.56	5.40	28.30	.....
Freiburg, B.	48 200	41.46	7.00	12.46	22.00	.....
Hamburg	583 700	58.00	2.87	.....	.....	.....
Hanover	189 976	18.40	1.15	4.26	13.00	.....
Halle	120 000	21.94	1.18	10.06	10.70	.....
Karlsruhe	74 200	28.14	8.64	6.20	13.30	.....
Kiel	72 000	20.18	2.22	2.09	15.46	0.41
Königsberg	162 000	16.87	1.21	2.06	13.60	.....
Magdeburg	198 000	25.24	2.22	20.60	0.01	2.43
Munich	298 000	34.00	1.00	31.30	1.70	.....
Nuremburg	145 000	17.41	4.03	8.10	3.35	1.93
Posen	70 000	13.33	2.01	9.22	0.06	2.04
Stettin	118 000	31.54	2.37	3.67	25.50	.....
Stuttgart	139 200	21.34	5.60	6.75	7.90	1.04
Wiesbaden	66 000	20.74	6.14	12.70	0.10	1.80
Wurzburg	61 032	35.50	.....	27.00	.....	.....
Zurich	96 650	56.71	6.76	19.45	30.50	.....
Average	.....	27.69	3.61	.....	.....	.....

No separate accounts are kept of the quantities of water used for manufacturing and domestic purposes, both being classed as water sold and paid for. Manufacturing is extensively carried on in many of the cities, but the writer judges that a much larger proportion of establishments have their own independent and cheaper supplies than is the case in America. This is particularly the case in Berlin, where even boilers in houses are commonly fed with well water, which is everywhere easily obtained, but is not allowed to be used for domestic purposes.

The Berlin water-works afford an unusually interesting example of

Mr. Hazen. accounting for all of the water pumped. The following table has been freely translated and slightly condensed from the annual report for 1892-93, and indicates only 2¼% of water lost through leakage, under-registration of meters and other causes:

WATER USED IN BERLIN, 1892-93.

	Cubic meters.	Percentage.	Gallons per head daily.
I.—For water-works purposes, feed water for boilers and testing meters	296 533	0.741	0.131
II.—Supplied without payment for public purposes.			
A.—METERED.			
Sprinkling public parks and gardens	264 986	0.662	0.118
Cleaning public monuments	261	0.001	0.000
Fourteen public ornamental fountains	702 079	1.754	0.311
Used by seven public closets and urinals	9 754	0.024	0.004
Used for military telegraph station	200	0.000	0.000
Used for flushing sewers	1 306 950	3 263	0.578
B.—ESTIMATED IN VARIOUS WAYS.			
Flushing gutters	82 056	0.205	0.036
Extinguishing fires	4 382	0.011	0.002
Street sprinkling	1 115 063	2.785	0.495
Watering trees in public streets	23 927	0.060	0.011
Used by 140 public closets and urinals	745 620	1.863	0.330
At the "Urania" exhibition	7 600	0.019	0.003
To this add loss through leakage, emptying and filling mains, under-registration of meters and some special uses	1 028 225	2.568	0.455
	5 290 603	13.215	2.343
III.—Used and paid for by water-takers by meter measurement	34 448 786	86.044	15.276
The water is thus divided as follows:			
I.—Water-works purposes	296 533	0.741	0.131
II.—Public purposes without payment and loss	5 290 603	13.215	2.343
III.—Paid for by water-takers	34 448 786	86.044	15.276
	40 035 922	100.000	17.750

It should be stated, however, that in calculating the quantity of water supplied, an allowance of 10% is made for the slip of the pumps.

In regard to the meters it might be said that in general all the water used in an apartment house is measured at one place, and paid for by the owner of the building, but on large services two meters, a large and a small one, are used, the larger meter registering the flow when the velocity exceeds the capacity of the smaller meter and the smaller meter registering when the flow is too slow to afford accurate results with the larger meter. The water is automatically taken through either one or the other of the meters, according to the velocity passing, and the sum of the quantities registered is the total quantity passed.

DEXTER BRACKETT, M. Am. Soc. C. E.—In reply to Mr. Thomson's inquiry, the author will say that the London districts were under constant supply, and the conditions were practically the same as in the case of Newton, Fall River and Worcester. The experience of the New York Engineers' Club is almost identical with that of hundreds of water-takers. Unseen leaks are allowed to continue for years, until the application of a meter and the presentation of a water bill proves their existence. Mr. Brackett.

Mr. Kuichling calls attention to the fact that the quantity used in the different months is much more uniform when the water is supplied through meters. This is without doubt due to the fact that the extravagant use of water during the summer, and the waste to prevent freezing of service pipes in the winter, are both largely prevented by the application of meters. The property-owner finds a way to protect his service pipe from freezing when he is obliged to pay for the water used.

While the author agrees with Mr. Le Conte that there will be in the future a legitimate increase in the per capita use of water, he does not believe that a supply of 200 galls. per head should be provided for our large cities. The use of water for hydraulic elevators and motors should not be encouraged, except where the supply is unlimited and near at hand.

There is no doubt but that the Deacon meter in sizes larger than 12 ins. would be cumbersome, but for general use in waste detection sizes larger than 6 ins. are rarely, if ever, wanted. The 6-in. meter is the only size found necessary in Boston, and in England the 4-in. meter is very generally used.

An experience of 15 years has never shown any necessity for placing the meter on a by-pass when used in connection with a pipe of the same size, on account of the danger that the waterway may become clogged, or because of the head lost. The custom in England is to place the meters directly on the line of the pipe, but the author has found it more convenient to place them under the sidewalk on account of convenience of access, and for the further reason that the 6-in. meters are often used in connection with 12-in. mains.

As the area of the waterway through the meter is equal to or larger than that of the pipe with which it is connected, it is difficult to understand how any substances found in drinking water could clog the meter, and, as the velocity through the meter seldom exceeds 5 ft. per second, the head lost is inappreciable.

Mr. Herschel claims that in the case of the Venturi meter no by-pass is needed, and that the head lost is a trifle. In the Venturi meter, as ordinarily made, the throat of the meter has a diameter one-third that of the pipe, with one-ninth of the area, and the velocity of the water is consequently increased nine times. It would seem prob-

Mr. Brackett. able that a 6-in. pipe contracted to an opening 2 ins. in diameter would be more liable to cause loss of head in a pipe system than the full area waterway of the Deacon meter.

Under some conditions, in large mains for example, where the changes in velocity are not great, the Venturi meter, without doubt, will give good results, but when it is remembered that the head varies as the square of the velocity, and that the quantities measured by the 6-in. Deacon meter vary from 1 000 to 15 000 galls. per hour, it is evident either that the head lost at the higher velocity will be excessive, or that the head at the lower velocity will be difficult to record.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

759.

Vol. XXXIV.—September, 1895.

THE SEPARATE SEWER SYSTEM WITHOUT AUTOMATIC FLUSH TANKS.

By F. S. ODELL, M. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, JUNE, 1895.

WITH DISCUSSION.

In the *Transactions* of this Society, Vol. X, page 29, the statement is made: "The flush tanks which make the separate system practicable are placed at the head of each branch sewer."

So far as the author is aware, this statement remains unchallenged in the literature on this subject up to the present time. It was held that unless a system of sewers excluding storm water was flushed by the artificial introduction of water at frequent intervals, stoppages would most assuredly occur, and to such an extent as to greatly impair, if not entirely vitiate, the usefulness of such a system. The supposed necessity for frequent flushing speedily brought into existence a number of excellent devices for automatically discharging the contents of storage tanks or cisterns when filled to a certain level, and thus it is possible to regulate the periods of flushing by limiting the streams by which the tanks are fed. These automatic flush tanks have been adopted almost universally as an integral part of the separate sewer system, and doubtless engineers still consider them indispensable adjuncts.

William E. Worthen, Past President Am. Soc. C. E., entertained serious misgivings concerning the virtue of frequent flushings of sewers with such small quantities of water as the capacity of the ordinary flush tank. The inadequacy of the water supply to furnish even the small additional quantity of water for operating flush tanks on the sewer system at Mount Vernon, N. Y., in the years 1888 and 1889, gave a convenient excuse to abandon the theoretical necessity of automatic flushing, and to test in a practical manner, on a sufficiently extensive scale, how a separate system of sewers would behave when flush tanks were entirely omitted. The system of sewers, about 20 miles, was therefore constructed without flush tanks. Manholes were located at all dead ends, and at intervals of about 400 ft. along the lines of sewers; the minimum size of pipe sewer was fixed at 8 ins. diameter, increasing in size in the district trunk sewers to 20 ins.; they were laid in the usual manner, true to line and grade, all changes in direction being made at manholes.

By an ordinance of the Health Department, all surface and storm water was excluded from the sewers, except that roof water from one or two buildings at each summit or dead end was allowed to enter for flushing purposes. The general inspector also deemed it wise to use additional precaution against stoppages, and therefore ordered frequent flushings from fire hydrants, introducing the water through 2½-in. hose into manholes along the line of sewers.

This was the condition of things in 1892, when, as Commissioner of Public Works under a new city charter, the author assumed charge of the sewer system. It was not without considerable trepidation and visions of serious trouble from clogged sewers, flooded basements and cellars, that the work of investigating the condition of the sewers was begun. Frequent connections with the sewers at that time materially aided in this examination, and disclosed a very wholesome and satisfactory condition indeed. No deposits were found, no gases could be detected, nor any objectionable odor.

It was not long, however, before an unexpected difficulty manifested itself. A severe rainstorm occurred, and a deep basement in the lower part of the city became flooded to a depth of 5 or 6 ins. An examination of the sewer in that vicinity showed an abnormal quantity of water standing 3 or 4 ft. in the nearest manhole. Continued observation of this locality at each recurring rainstorm established the fact

that too much storm water was finding its way into the sewers, and while not a little entered through the perforated covers of the manholes, it became evident that it came also from other sources. Up to this time no jurisdiction had been exercised by the municipality over the plumbing in buildings connected with the sewers, and no inspection made of any portion of the drainage system of dwellings or other buildings, save that portion of the drain within the limits of the street.

It became necessary to exclude storm water from the sewers. An ordinance was passed by the Common Council revoking all permits for connecting rain-water leaders with the sewers, and an inspector was appointed to enforce the ordinance. A house-to-house inspection was made of all premises connected with the sewers, and storm-water connections cut off wherever found. About this time the State law requiring plumbing inspection in all cities went into effect, so that all connections since made are subject to inspection and storm-water connections precluded. Complaints of back water from sewers have ceased, and, so far as known, storm water is now entirely excluded from the sewers.

During the year 1893 periodical flushing was continued, but frequent observations seemed to warrant the lengthening of the intervals between flushings, until in 1894 the intervals were extended to six months, and this period is now regularly maintained. The spring and fall seasons are selected for this work, there being an abundance of water available then. It is considered advisable to continue semi-annual flushing, although the necessity for it does not appear. In all new work the author is having direct connections made between the water mains and dead ends of sewers by the use of a 4-in. pipe and gate; with this the work of flushing is done very quickly and effectually.

It may be interesting to note here that during the three years covered by the author's observation and control of this sewer system, six stoppages have occurred. Two were occasioned by excavations carried below the sewers, the pipes being broken from settlement of the loose material; two more were caused by bedding and whole garments improperly permitted to enter the sewers; one stoppage was the result of coal tar escaping from the gas works, and last but not least, the same mischief was the work of the roots of a willow tree. Singularly enough, this last was the only stoppage in the lateral sewers; all the others occurred in district trunk sewers, with a constant flow of sew-

age, and so far removed from the dead ends as to be scarcely susceptible to the influence of flush tanks, had they been in use.

It is not the purpose of this paper to advocate the omission of flush tanks from all separate sewer systems, but to show they are not an essential feature; and when, from any sufficient reason, such as an insufficient or costly supply of water, they may be entirely dispensed with.

DISCUSSION.

Mr. Darrach. C. G. DARRACH, M. Am. Soc. C. E.—In the village of Ridley Park, Pa., where the speaker resided, there has been a separate system of sewerage for 16 years, which has grown gradually to a length of approximately 5 miles. The drains from the houses to the sewers are 3 to 4 ins. in diameter, and the sewers are 4, 6, 8 and 12 ins. in diameter. During the entire period of the speaker's residence in the town there had been no clogging of the sewers, although the only flushing water admitted to them is a small amount of rain water at the ends.

Mr. Hering. RUDOLPH HERING, M. Am. Soc. C. E.—The speaker was pleased to see the paper expressed the same views on automatic flushing which he had held for 16 years, but he was surprised to hear the author state it had been the general opinion of engineers that flush tanks were necessary for the proper operation of the separate system. In 1880 he inspected the existing separate sewerage systems in England, constructed in accordance with the principles since largely followed in this country, and they were not flushed by automatic flush tanks. He examined them very carefully by descending into the manholes, looking up the pipes and otherwise at all places where they were accessible, and found they were kept in very good condition without the use of such automatic flush tanks. He did not wish to be understood as opposed to these appliances in themselves; on the contrary, he had frequently recommended them. Under certain conditions they are very useful, economical and effective, particularly where the cost of water is low enough to permit the use of especially large tanks. He had found the automatic tanks of more advantage on steep than flat grades, the advantage being that the bulk of the water passes through the pipe somewhat like a piston, thus cleaning it more effectually. If the grades are light, discharges of 200 to 300 galls. generally lose their flushing power after passing a few hundred feet through the pipe, and 500 ft. from the tank he had sometimes been unable to detect any difence in the flow due to the operation of such an apparatus. While their use is to be recommended in many places, they certainly do not form an essential part of the separate system of sewerage.

CORRESPONDENCE.

Mr. Kiersted.

WYNKOOP KIERSTED, M. Am. Soc. C. E.—The author has raised an interesting point regarding the relation of automatic flush tanks to the separate system of sewers in assuming that engineers generally considered them indispensable adjuncts to separate sewerage. The quotation contained in the first paragraph of the paper refers specifically to the Memphis sewer system, and, like several other claims for that sewer system which were made at the time of its construction, has never been generally accepted as correct so far as the writer is aware. If the quoted statement has remained unchallenged in current literature, it is, perhaps, because the flushing of separate sewers, even though at times unnecessary, and the attachment to the sewer system of apparatus intended for that purpose do not in any particular affect prejudicially the operation of the sewers.

As the writer understands the question of flushing, the prevailing opinion among engineers is that while the flushing of sewers may be satisfactorily accomplished, so far as the immediate effect upon the sewers is concerned, by confining flushing water from a hydrant in a manhole at the summit of a lateral until full, then suddenly releasing it, or by means of a portable flush tank; still, in cases where frequent flushing is desired, the automatic flush tank affords an economical and convenient means of accomplishing the desired result in the upper portion of light grade lateral sewers, which seldom, if ever, flow more than a mere driblet of sewage containing solid matter but partially disintegrated. The question of flushing and the means to that end are associated largely with questions bearing upon the maintenance and operation of a sewer system after construction. In determining whether flushing is or is not necessary, the sewer gradient becomes a controlling factor. If flushing be thought necessary, considerations of economy in maintenance and operation usually decide, or should decide, whether automatic flush tanks or other flushing devices be used. This observation may apply, not only to the separate system of sewers, but also in a greater or less degree to the combined system.

The tendency of undisintegrated solids to deposit in the upper portion of a lateral sewer, and to thereby obstruct it, affects the flow of a sewer of heavy gradient much less than it does one of light gradient, as usually the accumulated head of sewage behind the obstruction in the former case would be sufficient to remove the obstruction, while in the latter case assistance by flushing or otherwise may occasionally be found necessary. In this connection it would be interesting to know the grades of the Mount Vernon sewer system.

So far as the writer's experience and observation affords a basis for

Mr. Kiersted. an opinion, he believes that the efficient flushing effect of the automatic flush tank is confined to a very limited length of sewer and that in many instances it may be dispensed with without prejudicially affecting the sanitary condition of the lateral sewer. Occasional flushing in the manner which the author describes will, in all probability, be found in many places other than Mount Vernon to meet all the demands for preserving cleanliness in the sewers of the separate or combined system, and often even more efficacious than the automatic flush tank for that purpose. In one sewer system which the writer designed he recommended an automatic flush only on laterals of less than 0.5% grade. The system has now been in operation five years with a record of but few stoppages. The minimum size of pipe is 8 ins., and all changes of direction are in the manholes.

Mr. Allen. KENNETH ALLEN, M. Am. Soc. C. E.—The extent to which automatic flush tanks may be omitted from sewers of the separate system is well worth consideration on the grounds of both sanitation and economy. It is a question of the relative amount of sludge to be transported and the available grade. The writer thinks, from the wording of the paper, that the erroneous impression might be received that the accredited omission of flush tanks is a novel practice, whereas, since the suggestion of a separation of the house sewage in England in 1842, by Mr. Edwin Chadwick, and its introduction soon after, it was a good many years before what is known as the automatic flush tank was introduced into sewerage works. In many instances the rain water from leaders was depended upon; in others, as in Liverpool to-day, portable tanks are emptied periodically into manholes, while in others all special means of flushing have been omitted.

The writer is a thorough believer in flushing sewers of the separate system by some method under ordinary conditions, but the experience at Mount Vernon has indicated that with good grades and well-built sewers, flush tanks are not as essential as is commonly supposed. The effect of the flush, it is true, does not extend far below the tank. To ascertain this decrease in the flow, the writer made a few observations of the discharges from Rhoads-Williams tanks put in by him at Fort Supply, I. T., some years ago. The results, which are given in the following tables, were for clean and empty sewers, receiving no other water. The pipes were in 2-ft. lengths and were laid to line and grade with exceptional care. As gaskets were not used, the work was new and the soil a perfectly dry open sand, it is probable that some slight loss from leakage occurred, but the amount was not ascertained. The results given are of course too meager in number and the local conditions were too unusual to afford a basis of calculation for other work, and are given here as there seems to be scarcely any printed data on the subject. They show clearly the limited value of the flush when there is not a good flow of sewage or a coincidence in the times of discharge.

Mr. Allen.

FLUSH TANK "H."

Capacity, 360 galls. Time to discharge, 46 seconds.

Reach.	Size of sewer.	Distance.	Grade.	Average velocity, front of discharge. Feet per second.	Duration of maximum discharge.	Maximum depth on invert (approximate).
Tank to Manhole 1.....	6 ins.	558 ft.	1.09%	5.03	1 min. 57 sec.	3½ ins.
Manhole 1 to Manhole 2.	6 "	260 "	1.79%	4.56	3 " 18 "	3 "
" 2 to " 3.	6 "	260 "	0.50%	3.17	2 " 30 "	3 "

FLUSH TANK "K."

Capacity, 360 galls. Time to discharge, 54 seconds.

Reach.	Size of sewer.	Distance.	Grade.	Average velocity, front of discharge. Feet per second.	Duration of maximum discharge.	Maximum depth on invert (approximate).
Tank to Manhole 4.....	6 ins.	680 ft.	0.52%	3.27	2 min. 30 sec.	3 to 5 ins.
Manhole 4 to Manhole 5..	6 "	484 "	0.40%	1.96	4 " 7 "	3⅜ ins.
" 5 to " 6*.	8 "	500 "	0.20%	1.33	.....	

* A slight current was flowing through this reach at the time of discharge.

FLUSH TANK "M."

Capacity, 230 galls. Time to discharge, 32 seconds.

Reach.	Size of sewer.	Distance.	Grade.	Average velocity, front of discharge, Feet per second.	Duration of maximum discharge.	Maximum depth on invert (approximate).
Tank to Manhole 7.....	6 ins.	575 ft.	2.8%	6.25	.....	Full.
Manhole 7 to Manhole 8.	6 "	260 "	0.5%	3.56	.....	2½ ins.
" 8 to " 9.	6 "	321 "	0.5%	1.86	1 min. 20 sec.	3 "
" 9 to " 10*	8 "	775 "	0.2%	1.17	.....	.....

* This reach was somewhat soiled when measurements were made.

FLUSH TANK "N."

Capacity, 379 galls. Time to discharge, 1 minute.

Reach.	Size of sewer.	Distance.	Grade.	Average velocity, front of discharge. Feet per second.	Duration of maximum discharge.	Maximum depth on invert (approximate).
Tank to Manhole 11.....	6 ins.	435 ft.	0.4%	3.95	.....	2½ ins.
Manhole 11 to Manhole 12	8 "	500 "	0.2%	1.35	2 min. 30 sec.	2½ "
" 12 to " 13	8 "	500 "	0.2%	0.91	.....	1½ "
" 13 to " 14	8 "	500 "	0.2%	0.74	6 min. 3 sec.	1½ "

Mr. Folwell. A. PRESCOTT FOLWELL, Assoc. M. Am. Soc. C. E.—The writer believes that the author takes too literally the wording of the quotation forming his text. He does not think it has ever been generally claimed that "flush tanks" make the separate system practicable, but it has undoubtedly been claimed that flushing does so, and flush tanks are usually recommended and employed, and are cheaper and more reliable than flushing by means of a hose or other appliance when intrusted to careless employees. The writer knows many engineers who do not consider tanks indispensable. In most of the systems which he has designed he has recommended the use of flush tanks, but has suggested other methods for attaining the same end should there be any reason for omitting them. The experience of several of these systems which have for a time dispensed with them will be referred to later.

After a careful reading the writer is in doubt whether the author wishes to challenge the correctness of the quoted statement should flushing be substituted for flush tanks. He claims that "flush tanks * * * are not an essential feature of * * * all separate sewer systems." The writer hopes he will state whether, as the result of his experience, he considers flushing necessary for all separate sewer systems, and also that he will give the minimum grades in the Mount Vernon sewers, the average consumption of water per capita and the probability of ground water entering the pipes to any extent through the joints. The data must be definite on these points, for if it shall prove practicable to omit flushing in any or all systems or parts of systems, many towns contemplating constructing sewers may be spared a considerable expense, both in construction and in maintenance.

In the writer's experience he has omitted flush tanks in the designs in two cases where the grades were considerable, 8% to 12%, and a public water supply already introduced into these streets, and stated his belief that no flushing would be required, but recommended a flushing by hose at intervals of a few months. Both of these steep lines, however, being on the outskirts of cities, are as yet unbuilt and cannot be quoted as examples of either right or wrong construction. If they shall prove to be the latter, flush tanks can easily be added at any time.

In two more cases where conditions were different, experience did not favor the omission of flush tanks. In both these cases the grades were, with few exceptions, those theoretically giving a velocity of 2½ ft. per second, the pipes were carefully graded and jointed and no ground water or mud could enter the sewer through the joints. Flush tanks were provided for at the head of each branch, but not set until the entire plant was completed. Meantime, under pressure from many householders, the authorities permitted connections to be made with the sewers and used as soon as an outlet was provided. In each case these connections were used for two or three months before the tanks

were in operation. At the end of that period an inspection showed that there were many stoppages from house waste, aside from those occasioned by garbage, ashes and old clothes, and that almost every dead end emitted many foul odors. It is possible that this condition would not have existed were all the properties along each sewer branch using it freely. But this is a condition which is not found for several years after construction in many of the lateral branches of a system. Where the grades were steep, in two short sections they exceeded 6%, no stoppages were discovered and there was no odor whatever. Mr. Folwell.

This experience of so short duration cannot be considered as outweighing that of Mount Vernon. But the writer cannot see how a longer existence of the conditions would have improved matters or rendered the conclusions less favorable to the necessity of flushing. The separate system as generally constructed and operated is distinctly a water carriage system and relies for its success upon a sufficiency of water properly applied. If the ordinary house water answers this purpose a great saving may be effected.

WILLIAM B. LANDRETH, M. Am. Soc. C. E.—A majority of the separate sewerage systems as designed and built during the past 10 or 12 years have been provided with some means of regular flushing, generally by some form of automatic flushing tank. As is well known, the water passing through a sewer must have at least a certain velocity of flow to carry the heavier particles of sewage and prevent their stranding in the pipe. The minimum cleansing velocity depends upon the size and rate of fall of the sewer, and the quantity of water necessary to secure that velocity must be supplied in some manner if the sewer is to be kept clean. If sufficient water were furnished from house connections or entered the sewer through the joints, artificial flushing would be unnecessary, and the quantity of water supplied from those sources are important factors in deciding if automatic tanks are needed. Both of the sources mentioned are uncertain and their combined flow difficult of determination, owing to the fact that the leakage into the pipes generally decreases with the age of the sewer, while the number of house connections which will probably be made during the early stages of its use can rarely be foretold. There seems to be greater need of frequent and regular flushing during the first year or two of the use of the sewers than later, when the quantity of sewage from the house connections has increased and is sufficient to flush them properly. Mr. Landreth.

In a properly designed system where the sizes and grades of the sewers are such as to give a cleansing velocity to the sewage when the pipes are running half full, as soon as sufficient sewage is flowing to keep the sewer clean, the flush tanks are useful mainly in flushing the upper portions of the system, from the tank to a point in the sewer where a cleansing flow is found. In a system already constructed, the

Mr. Landreth. interval between successive flushings can be readily determined by experiment, and will generally vary in different portions. Where regular flushing of a system of sewers has been found necessary, it is the belief of the writer that the cheapest method of applying the water is by means of automatic flush tanks. With flush tanks holding 300 galls. each, and with an average of four tanks per mile of sewer, the daily quantity of water necessary for one flushing would be 1 200 galls. per mile, or 24 000 galls. for a system of 20 miles, costing probably less than $2 50.

Some separate systems have been designed and built with such low grades that a cleansing velocity could never be obtained, and the flushing of such systems in any manner would be of little use. It has been the practice of the writer to use some form of automatic flush tank on all separate sewers, where water for feeding them could be secured; but he is not prepared to say that they could not have been omitted in some cases without detriment to the operation of the system. Experience gained in the construction and care of several hundred flush tanks, of several forms and under varying conditions, has taught him that some will work and some will not; some will work with a small trickle, while others need to be flooded with a strong stream; some will work for a while, but refuse to operate after a time.

Mr. Le Conte. L. J. Le Conte, M. Am. Soc. C. E.—Most sanitary engineers will agree with the author that automatic flush tanks are not inseparable adjuncts to the separate system. The effects of a 150-gall. flush are all expended a few hundred feet away from the tank, the distance varying with the grade of the sewer. Where grades are light and the flush is most needed they do the poorest work, and some auxiliary means have to be adopted to furnish a long, continued flush, preferably a pipe connection with the city water main. Two cities in California, Oakland and Alameda, the former with 60 000, and the latter with 10 000, population, have strongly contrasting separate systems. Oakland has some 100 miles of pipe sewers on the separate system, without flush tanks. The only storm water allowed to enter the sewers is roof water at and near the upper ends of the streets. The sewers are flushed regularly two to three times a year by means of a line of hose attached to fire hydrants. This is done during the dry season. In the city of Alameda the flush tank system is in use. The tanks are located not only at the upper ends, but also at various intervals along each street sewer down to the outfall into the main intercepter. Sometimes these tanks flush regularly three times a day, and sometimes they do not work at all, but the results seem to remain the same. The writer does not believe in the efficiency of these small flushes; they are impotent and waste a large amount of water to no practical purpose. The tanks are expensive and require constant attention. One good, continuous flush from a water main he considers worth a myriad of tiny flushes from tanks. It is cheaper, more effective and requires less water.

Mr. Le Conte.

The Oakland system compares most favorably with that in Alameda in every respect. The only trouble with choking has been due to roots of trees finding their way through the cemented joints, and finally filling the whole bore of the pipe, often bursting the joints. Many beautiful rows of shade trees had to be cut down on this account. A growth of trees near an aqueduct, sewer or masonry reservoir is a constant menace to the work. The roots of eucalyptus trees near a service reservoir at the Mare Island Navy Yard penetrated through the brick masonry wall, 4 ft. thick, and finally cracked it so badly that a serious leak was developed. On emptying the reservoir, the bottom was found to be covered with a mat of roots, 325 sq. ft. in area and some 12 ins. thick. Where the main root passed through the fissure in the wall, it was like a mammoth saw-blade not over $\frac{1}{8}$ in. thick.

Mr. Odell.

F. S. Odell, M. Am. Soc. C. E.—While all who engaged in the discussion of this paper have expressed the opinion that flush tanks were not essential to the proper working of the separate system of sewers, the author believes the fact remains as stated by Mr. Landreth, that the majority of such systems designed and built during the past 10 or 12 years have been provided with some form of automatic flush tank. This would imply that the designers believed either that they were necessary, or that they were efficient and economical. The author has come to believe they are neither, but that a direct connection with the water mains gives a much better flushing, and in the course of the year uses far less water. His experience has been that flush tanks discharging 200 galls. or less of water fail to flush a sewer properly, especially on the flat grades where flushing is most needed. The grades at Mount Vernon are mostly good, from 0.5 to 6%, the flattest grades being 0.25%, and on all these sewers a good flushing twice a year answers every purpose.

Regarding the cost, it may be interesting to note a comparison with a neighboring municipality, New Rochelle, where flush tanks are used on all dead ends. It has 40 tanks and during the year ending January 9th, 1895, used 5 400 000 galls. of water. Under contract with the water company, it pays at the rate of $12 per annum for each flush tank, using a maximum quantity of 60 000 galls.; for all water used in excess of this quantity payment is made at the rate of 5 cents per 1 000 galls; under this arrangement the water bill for the year amounts to $630 21. Mount Vernon, with double the number of dead ends, must necessarily have paid twice that amount, or $1 260 42. As a matter of fact, the quantity of water used in flushing the sewers of Mount Vernon for the year 1894 was about 500 000 galls., as determined by the quantity pumped during the flushing period, in excess of the normal consumption. This, at the maximum price paid at New Rochelle, would amount to $100, showing a saving of $1 160 on water; while the cost of labor is much less than the cost of inspection of the flush tanks.

Mr. Odell. It is impossible to estimate the per capita consumption of water in a suburban city such as Mount Vernon, where, perhaps, a majority of water-takers use it liberally in lawn sprinkling during the summer season, when the smallest quantity of ground water finds its way into the sewers. Nor can the quantity of ground water reaching the sewers be definitely determined. In the lateral sewers where flushing is most needed, the quantity is very small, as such sewers are located on the high and dry grounds of the city.

The author does not think it judicious to omit provision for flushing in the design or construction of a separate system of sewers. The cost of connecting the water main by a 4-in. branch and gate with the manhole at the dead end of a sewer is about $40, which is a very small item. It is the simplest and best method of flushing the author has yet tried, and he strongly recommends its use. Flushing through a hose from fire hydrants is slow, and consequently much more expensive than by means of a gate on the water main.

Doubtless the automatic flush tank was expected to so cleanse the sewer on which it was placed that no material susceptible of decomposition could remain stranded during the passage of the water from the tank, but observation and experiment seem to discredit such an assumption; consequently, the sanitary condition of a sewer that is effectually flushed two or three times yearly is found to be as good as, or better than, one superficially flushed by small daily discharges from automatic tanks.

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EXPERIMENTS ON THE DISCHARGE OF A 30-IN. STOP VALVE.

By J. WALDO SMITH, Assoc. M. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, JUNE, 1895.

WITH DISCUSSION.

In connection with the measurement of the flow of the Pequannock River and the operation of the water supply system built by the East Jersey Water Company for the city of Newark, N. J., it became desirable to ascertain the discharge of certain 30-in. stop valves at the outlets of the storage reservoirs. The author was directed by the chief engineer, Clemens Herschel, M. Am. Soc. C. E., to make the necessary gaugings, a brief description of which, with a tabulation of results obtained, may be of interest to members of this Society. Opportunities for making careful experiments of this kind are comparatively rare, and when they do arise it seems to the author that the results should be placed where they may be of general use to members of the profession, such description being presented in as

brief a form as is consistent with entire clearness and still be sufficiently detailed to serve as a true guide for their further application.

The valve selected for experiment was one of four of the same pattern and workmanship, located in the gate house at the outlet of Clinton Reservoir. Figs. 1 and 2 show the general arrangement of the pipes and gates, the channels of approach and discharge, and the location of the measuring weir. The experiments numbered 1 to 5, inclusive, were made with the gate numbered 1, and the remainder with No. 3.

It will be noticed that in constructing the discharge pipes and gates use has been made of the Venturi principle, by setting the gate at the common apex of the frustums of two cones, enlarging in both directions to 42 ins. in diameter, and terminating in a short piece of straight pipe at the lower end and in a piece of straight pipe and a "flap gate" at the upper end. The flap gate is intended for use should the 30-in. valve become seriously disarranged, necessitating its removal, and was wide open, as shown, at the time of the experiments. The valve was made by the Ludlow Valve Manufacturing Company, of Troy, N. Y., in 1891, and has two parallel cast-iron disks, with faces about 6½ ins. apart. Fig. 3 shows the details of the gate.

The reservoir having been emptied a few days after the experiments were finished, opportunity was thus afforded to make the necessary measurements of the valve. The brass gate rings were found to be 32.96 ins. in diameter, and the brass seat rings 30.22 ins. in diameter. Careful measurements were also made of the cast-iron lug a at the bottom of the disks. The area of the lune-shaped orifice of discharge for different positions of the disks was computed from the above measurements, and the results are given in Table No. 1. There, and in all cases in this paper, "height of gate" refers to the clear height of the bottom of the gate ring above the top of the seat ring, and is represented by the distance b in Fig. 3. The headings of the remaining lines are self-explanatory. Lines 1 and 2 of this table were plotted as ordinates and abscissas, and a diagram constructed, from which the area of the lune-shaped orifice for any gate opening could be read at a glance. Correction for the cast-iron lug a was made by deducting the area of its longitudinal cross-section from the area of the lune-shaped orifice for all heights of gate greater, and the proportional part of such cross-section opposed to the discharge for heights

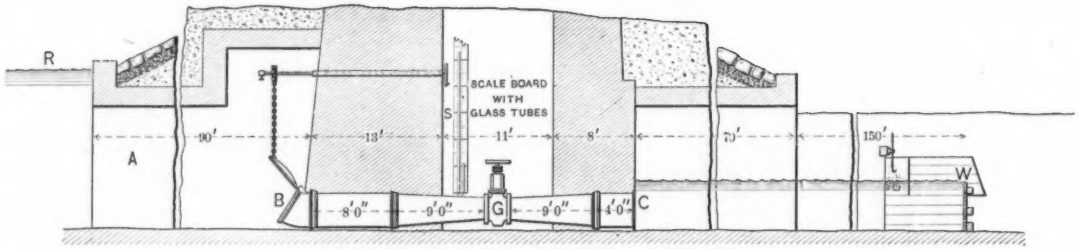

Fig. 1. SECTION THROUGH GATE-HOUSE ARCH-WAY AND WEIR.

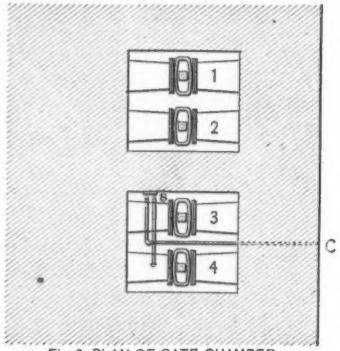

Fig. 2. PLAN OF GATE CHAMBER.

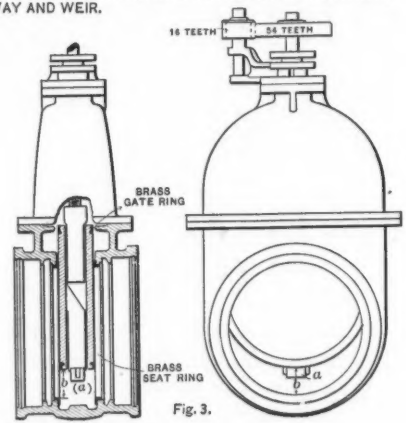

Fig. 3.

of gate less, than the depth of the lug. The areas given in Table No. 2, column 4, are the net areas with the lug deducted.

The height of the gate was observed by means of an indicator, which was carefully rated when the reservoir was empty. To do this the gate was raised to any height and the corresponding distance *b*, Fig. 3, of the bottom of the disk ring above the seat ring was measured and compared with the height shown by the indicator. In all the experiments the gate was set on the opening movement so as to avoid errors from back-lash.

TABLE No. 1.

GIVING AREAS OF LUNE-SHAPED ORIFICE IN A 30-IN. STOP VALVE FOR DIFFERENT HEIGHTS OF GATE.

Height of gate. Inches.....	1.	3.	5.	8.	12.	16.	20.	23.	25.	27.5	30.2
Area of opening. Square feet.	0.101	0.451	0.869	1.496	2.308	3.070	3.761	4.213	4.474	4.738	4.901
Proportional height of gate...	0.033	0.099	0.165	0.265	0.397	0.530	0.662	0.761	0.828	0.911	1.000
Proportional area of opening..	0.021	0.092	0.177	0.305	0.471	0.626	0.767	0.860	0.913	0.967	1.000

In conducting the experiments the water was drawn from the reservoir *R* (see Fig. 1), through the archway *A*, discharged through the gate *G*, and measured over the weir *W*. The height of the water was observed at *B*, just at the inlet of the pipes, by tapping one of the unused pipes, No. 4, above the gate, and piping to a glass tube on the scale board *S*. A pipe through the down-stream wall of the gate-house served to bring the water from *C*, just at the outlet of the pipes, into the gate chamber, where its height was observed on the same scale. The pipes were so arranged that a full stream of water could be run through them, to ensure freedom from entrained air before any observations were made. After passing the pipe and gate the water flowed through an archway and open rock cut about 220 ft. to the weir *W*.

The crest of the weir was of hard pine, the plane of the up-stream side being vertical, and the edge presented to the current being sharp; the down-stream side was chamfered so that the water in no case touched any part of the weir after passing the up-stream edge. The sides of the channel of approach were of planed matched boards, those at the ends of, and above, the weir, extended a short distance down stream from the crest, thus preventing the expansion of the sheet after passing the weir. Provision was made for a free circulation of air under

the sheet. The depth on the weir was measured by means of a hook gauge securely fastened to a large timber, whose ends rested in the rock sides of the cut. The hook gauge pail, placed on a movable bracket, was connected by means of a rubber tube and a brass pipe with an orifice in a brass plate set in the side of the flume. This orifice was normal to the plane of the plate, which was perfectly smooth and true, and was about 0.20 ft. below, and 6 ft. up stream from the line of the crest of the weir. The end contractions were suppressed, and the length of the weir was exactly 12 ft. The mean depth of the channel of approach below the crest of the weir was 4.07 ft. No racks were used to quiet the water, but the sheet went over the weir in good form, although with the greatest depths, 2 ft. and above, there was an oscillation of the surface level, amounting to 0.13 ft., which was not, however, communicated to the surface of the water in the hook gauge pail.

TABLE No. 2.

Record of Observations and Results of Computations.

1	2	3	4	5	6	7	8	9	10	11
Date, 1892.	No.	Height of gate. Inches.	Area of opening A. Square feet.	Depth on Weir. Feet.	Water passing weir Q. Cubic feet per second.	Reading of Head Gauges. Upper. Feet.	Reading of Head Gauges. Lower. Feet.	Head on gate H. Feet.	Coefficient of discharge, $\frac{Q}{A\sqrt{2gH}}$	Quantity in column 6 reduced to head of 9 ft.
Aug. 23...	1	11.9	2.29	1.142	49.30	64.60	53.79	10.81	0.816	44.98
" ..	2	3.9	1.68	0.934	36.35	64.58	53.63	10.95	0.815	32.95
" ..	3	5.9	1.07	0.713	24.10	64.58	53.45	11.13	0.842	21.67
" ..	4	3.0	0.45	0.443	11.75	64.58	53.21	11.37	0.965	10.45
" ..	5	0.9	0.09	0.228	4.35	64.58	53.00	11.58	1.771	3.83
" ..	6	3.3	0'51	0.452	12.10	64.58	53.20	11.38	0.877	10.76
" ..	7	7.2	1.33	0.808	29.15	64.58	53.50	11.08	0.821	26.27
" ..	8	11.2	2.15	1.075	45.02	64.57	53.64	10.93	0.790	40.85
Aug. 26..	9	1.3	0.15	0.225	4.25	62.78	58.00	9.78	1.130	4.08
" ..	10	3.6	0.57	0.458	12.40	62.79	53.22	9.51	0.877	12.03
" ..	11	6.6	1.21	0.712	24.08	62.79	53.45	9.34	0.811	23.61
" ..	12	9.6	1.82	0.916	35.25	62.79	53.59	9.20	0.796	34.86
" ..	13	12.6	2.44	1.106	47.00	62.79	53.69	9.10	0.796	46.74
" ..	14	15.5	2.97	1.292	59.50	62.78	53.84	8.94	0.835	59.70
" ..	15	18.5	3.51	1.529	76.95	62.77	54.02	8.75	0.924	78.04
" ..	16	21.5	3.99	1.781	97.05	62.76	54.18	8.58	1.035	99.40
" ..	17	24.5	4.40	2.081	123.25	62.67	54.34	8.33	1.210	128.11
" ..	18	30.2	4.90	2.320	145.95	62.66	54.46	8.20	1.297	152.90
Aug. 30...	19	30.2	4.90	2.100	125.00	60.54	54.36	6.18	1.279	150.85
Sept. 4..	20	25.5	4.52	1.494	74.25	56.73	54.06	2.67	1.254	136.32
" ..	21	22.8	4.18	1.332	62.30	56.73	53.96	2.77	1.117	112.30
" ..	22	27.5	4.74	1.556	78.95	56.72	54.11	2.61	1.286	146.61
" ..	23	30.2	4.90	1.584	81.15	56.72	54.14	2.58	1.286	151.57

The flow over the weir was computed by the Francis formula, $Q = 3.33\ L\ H^{\frac{3}{2}}$, in which Q is the discharge in cubic feet per second, L is the length of the weir in feet, and H is the depth on the weir in feet. Correction was made for velocity of approach.

The hook gauge was observed every minute, and the head gauges, which scarcely varied at all during a single experiment, every five minutes.

Table No. 2 gives a tabulation of the observations and results. Col-

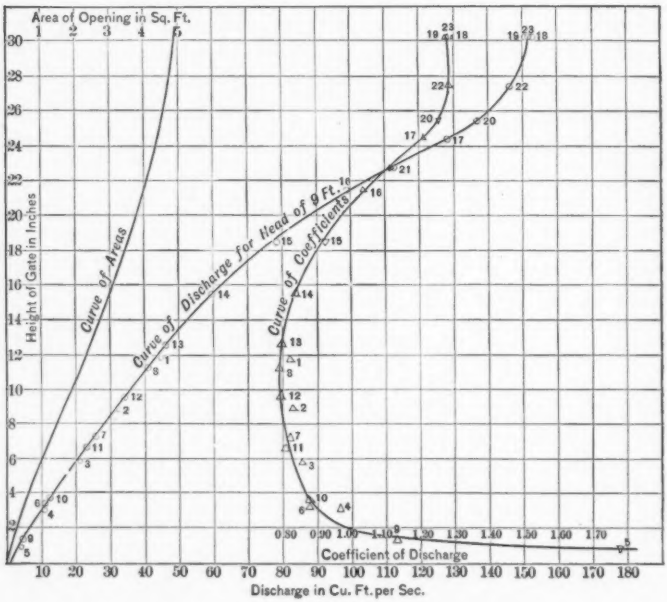
Area of Opening in Sq. Ft.
Height of Gate in Inches
Curve of Areas
Curve of Discharge For Head of 9 Ft.
Curve of Coefficients
Coefficient of Discharge
Discharge in Cu. Ft. per Sec.

FIG. 4.

umn 3 gives the clear height of the bottom of the disk ring above the seat ring, and is represented by the distance b in Fig. 3. Column 4 gives the net area of the lune-shaped opening, correction having been made for the lug at the bottom of the disks. Column 9 shows the difference between the height of water at the inlet and outlet of the 42-in. pipe, points B and C in Fig. 1. The headings of the remaining columns are self-explanatory. The results of the experiments are more clearly shown by the curves in Fig. 4. A good degree of regularity will be

noted in the plotted points for experiments made with different gate openings, and with a considerable variation in head, thus proving the accuracy of the experiments.

In experiments Nos. 1 to 5, some doubt existed as to the indicator being in good working order, and in No. 18 the depth on the weir was too great for a good measurement, the water striking the cap timbers; consequently those experiments are not entitled to as much weight as the others. The coefficients given in column 10 are not, strictly

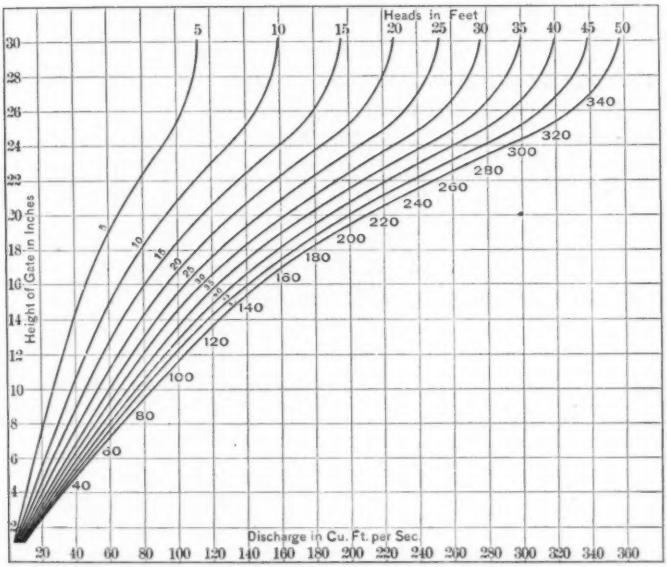

FIG. 5.

speaking, coefficients of discharge of the gate alone, but of the gate and the short lengths of connecting pipes. The head might have been observed immediately above and below the gate, but it would have been difficult to get satisfactory readings, and, in the present case, would have served no practical purpose.

The upper half of the curve of coefficients is quite different from that found by E. Kuichling, M. Am. Soc. C. E., for a 24-in. stop valve.* This disagreement is to be expected when the differing conditions are

* See the *Transactions* of the American Society of Civil Engineers, Vol. XXVI, p. 439.

considered. In Mr. Kuichling's case, as the disks were raised, the limit of the coefficient with the full opening of gate was infinity, while in the present case the coefficient approached a certain definite limit. Up to half gate there is a similarity in the curves, and as near an agreement as could be expected considering that the gates are used in different ways, and for a different purpose.

In applying these results to approximately the same sizes of gate set in the same manner as the one experimented upon, Table No. 3, which is computed from the curves, will be found useful.

TABLE No. 3.

PROPORTIONAL VALUES FOR HEIGHT OF GATE, AREA OF LUNE-SHAPED OPENING, AND DISCHARGE.

Proportional height of gate.....	0.125	0.250	0.375	0.500	0.625	0.750	0.875	1.000
" area of opening....	0.125	0.287	0.443	0.593	0.729	0.851	0.946	1.000
" discharge.....	0.086	0.178	0.274	0.384	0.533	0.734	0.936	1.000

In Fig. 5 is given a diagram of the discharge of the 30-in. gate for each 5 ft. of head up to 50 ft., based on these experiments.

DISCUSSION.

Mr. Kuichling. E. KUICHLING, M. Am. Soc. C. E.—The data contained in the paper deserve careful attention as they relate to a very large valve, while the similar data given in the familiar manuals on hydraulics were derived from experiments with very small valves. In character the experiments now submitted are like those made a few years ago with a 24-in. stop-valve at Rochester, N. Y.,* but as the author states that the values of certain coefficients found by him are considerably different from those obtained in the paper referred to, the speaker desired to make some comments concerning them.

The coefficients mentioned by the author as not being in accord with those found from the aforesaid experiments with a 24-in. stop-valve are simply the coefficients of discharge computed from the given data on the assumption that the orifice presented by the valve opening is in a comparatively thin wall and is fully submerged. These coefficients were originally computed for the purpose of a collateral analysis respecting the flow of water in pipes, and were submitted in the paper mentioned in the hope that they might be utilized by others who had more time than the speaker to complete such an analysis. To present the matter clearly, the following notation was adopted: $Q =$ discharge through valve in cubic feet per second; $A =$ area of orifice in square feet; $H =$ total observed loss of head in feet in the entire apparatus, as given by the author in column 9 of Table No. 2 of the paper, this being the difference in level between the water surface in the reservoir and that in the flume above the measuring weir; $2g =$ twice the acceleration due to gravity $= 64.4$ ft. per second; $y =$ loss of head due to the passage of the volume Q through the valve orifice alone, while $x =$ loss of head in the remainder of the apparatus, so that $x + y = H$; and, finally, $\mu =$ coefficient of discharge for the valve opening considered as a submerged orifice in a comparatively thin wall. There then exists the well-known relation:

$$(1) \ldots\ldots\ldots\ldots Q = \mu A\sqrt{2gy}, \text{ whence } \mu = \frac{Q}{A\sqrt{2gy}}.$$

It should be remarked that it was on this basis that the coefficients μ were computed in the speaker's paper already mentioned. The author, on the other hand, has computed coefficients on the basis of taking the entire observed loss of head H in the entire apparatus, instead of only the portion y relating to the valve alone, and has made: $\mu = \frac{Q}{A\sqrt{2gH}}$. Obviously the resulting values of μ cannot agree with those derived by considering the partial loss of head y

*See the *Transactions* of the American Society of Civil Engineers, Vol. xxvi, p. 439.

Mr. Kuichling. alone; and it now becomes of interest to ascertain the proper values of y in the author's experiments, whereupon a new computation of the coefficients μ will enable a proper comparison to be made with those for the 24-in. valve.

To determine the proper values of y in the case under consideration, it is advisable to deduce from the given data the relation between Q and H when the 30-in. valve is fully open, in which event $y = 0$ and $H = x$. For this purpose experiments Nos. 18, 9 and 23 of Table No. 2 are at once available, and as the author's values of μ are practically constant, the following equation is obtained therefrom directly: $Q = c\sqrt{H}$, whence:

$$(2)\ldots\ldots\ldots H = x = \left(\frac{Q}{c}\right)^2 = 0.00039106\ Q^2.$$

This expression accordingly represents the relation between the loss of head in the apparatus exclusive of the valve (which is fully opened) and the discharge Q, and by constructing the parabolic curve represented thereby with x as ordinates, and Q as abscissas, the value of x for any value of Q given in the author's Table No. 2 may then be quickly found. The difference between these values of x and the corresponding values of H will then give the proper values of y sought, whereupon their substitution in equation 1 will yield the values of the coefficient μ which may properly be compared with the ones obtained from the 24-in. valve. By this process the values given in Table A were obtained.

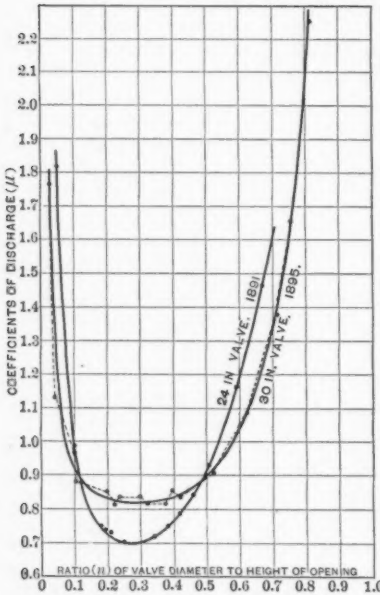

FIG. 6.

If the values of μ in column nine of the foregoing table are plotted as ordinates to the corresponding values of n in the second column as abscissas, the line connecting the several points thus obtained will be seen to be somewhat irregular; but by passing a curve through the line so as to cut off the irregularities, this curve will be found very similar in shape to that which was found for the case of the 24-in. valve. For the purpose of exhibiting this similarity, the two curves are shown in Fig. 6.

Mr. Kuichling.

It may be remarked that the irregularities indicate some slight errors in the original observations which are closely revealed by the above development of the coefficient μ; also that the results obtained from the observations on the 24-in. valve by means of the mercurial pressure-difference gauge, described in the paper mentioned, are remarkably free from irregularities. The difference between the numerical values of μ for the 30-in. and 24-in. valves is clearly exhibited

TABLE A.

Showing Observed Data and Results of Original and Revised Computations.

1	2	3	4	5	6	7	8	9
Number of experiment.	Ratio of diameter of valve to height of opening n.	Area of opening A in square feet.	Discharge through opening Q in cubic feet per second.	Total observed head H in entire apparatus. Feet.	Computed loss of head x in apparatus except valve. Feet.	Computed loss of head y in valve alone. Feet.	Coefficient of discharge μ computed with H.	Coefficient of discharge μ computed with y.
1.....	0.394	2.29	49.30	10.81	0.94	9.87	0.816	0.854
2.....	0.295	1.68	36.35	10.95	0.51	10.44	0.815	0.835
3.....	0.195	1.07	24.10	11.13	0.21	10.92	0.842	0.849
4.....	0.099	0.45	11.75	11.37	0.05	11.32	0.965	0.967
5.....	0.029	0.09	4.35	11.58	0.01	11.57	1.771	1.771
6.....	0.109	0.51	12.10	11.38	0.06	11.32	0.877	0.879
7.....	0.238	1.33	29.15	11.08	0.32	10.76	0.821	0.833
8.....	0.371	2.15	45.02	10.93	0.79	10.14	0.790	0.819
9.....	0.043	0.15	4.25	9.78	0.01	9.77	1.130	1.130
10.....	0.119	0.57	12.40	9.51	0.06	9.45	0.877	0.882
11.....	0.218	1.21	24.08	9.34	0.21	9.13	0.811	0.821
12.....	0.318	1.82	35.25	9.20	0.49	8.71	0.796	0.818
13.....	0.417	2.44	47.00	9.10	0.86	8.24	0.796	0.836
14.....	0.513	2.97	59.50	8.94	1.38	7.56	0.835	0.908
15.....	0.612	3.51	76.95	8.75	2.30	6.45	0.924	1.076
16.....	0.712	3.99	97.05	8.58	3.69	4.89	1.035	1.371
17.....	0.811	4.40	123.25	8.33	5.93	2.40	1.210	2.253
18.....	1.000	4.90	145.95	8.20	8.31	0.00	1.297	∞
19.....	1.000	4.90	125.00	6.18	6.10	0.00	1.279	∞
20.....	0.844	4.52	74.25	2.67	2.15	0.52	1.254	2.530
21.....	0.755	4.18	62.30	2.77	1.51	1.26	1.117	1.655
22.....	0.911	4.74	78.95	2.61	2.42	0.19	1.286	4.762
23.....	1.000	4.90	81.15	2.58	2.58	0.00	1.286	∞

in the diagram; and the only comment which can now be made on the results is that the failure in agreement points out the fact that the laws which govern the motion of water in pipes are not yet definitely known. Owing to this circumstance, the paper cannot fail to be a welcome and valuable addition to the knowledge of the subject, and the speaker hoped that further contributions of a similar character will be offered.

CORRESPONDENCE.

Mr. Smith. J. WALDO SMITH, Assoc. M. Am. Soc. C. E.—Mr. Kuichling has treated the subject so exhaustively that there is little more to be said. The author did not compute the coefficient, μ, for the reason that in the work which called forth the experiments it would have served no practical purpose, for the result wanted was the discharge of the gate and connecting pipes with any elevation of water in the reservoir, and he was satisfied to present the facts just as they came to him, with a full explanation of the method of making all the observations, so that any one could adapt the results to suit the case in hand. He is very glad, however, that Mr. Kuichling has taken so much trouble to reduce the experiments to a form to make them directly comparable with his own and others, for their whole range.

In regard to the greater regularity of the coefficient, μ, as given by the experiments of Mr. Kuichling, the author thinks this regularity is not so much due to the use of the pressure-difference gauge as to the fact that the μ, as he understands from a careful perusal of the above experiments, is the result of a computation from adjusted quantities, and not from the actual experimental observations, *i. e.*, in the formula* $\mu = \frac{Q}{F\sqrt{2gy}}$, the loss of head appears to have been adjusted by plotting the experimental values as obtained from the pressure-difference gauge, drawing a curve, and reading new values of y, from this curve, thus eliminating any irregularities or errors in the original observations; Q is computed by formula, so the resulting quantity, μ, would necessarily show great regularity.

* See the *Transactions* of the American Society of Civil Engineers, Vol., XXVI., p. 449.

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761.

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CONSTRUCTION OF SUBSTRUCTURE FOR LONESOME VALLEY VIADUCT, KNOXVILLE, CUMBERLAND GAP AND LOUISVILLE RAILROAD.

By GUSTAVE R. TUSKA, Jun. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, JUNE, 1895.

WITH DISCUSSION.

About 60 miles from Knoxville, Tenn., the Knoxville, Cumberland Gap and Louisville Railroad crosses Lonesome Valley on a viaduct about 800 ft. long and at a maximum height above the valley of 135 ft. Formerly the railroad crossed this valley on a wooden trestle which collapsed while a freight train was upon it, its collapse being due to its meager bracing. The railroad company having decided to reconstruct this viaduct, William Barclay Parsons, M. Am. Soc. C. E., the consulting engineer of the road, made designs and specifications for the work. The structure is a single-track steel viaduct of fourteen 30-ft. and five 70-ft. deck spans, the 70-ft. spans being latticed girders, while plate girders are used for the 30-ft. spans. The towers are of the ordinary type, in which all connections are riveted. Besides the two abutments, there were required to be constructed 36 piers for the towers of the viaduct.

The only rock to be found in this locality is a light limestone, which deteriorates rapidly. Some bridge abutments on this railroad built of this stone but a few years ago show the stone in a very poor condition. The bids for masonry, built of this material, ran from $12 to $16 per cubic yard. A much better substructure could be constructed by using concrete made from this same limestone. Furthermore, concrete made with the best sand and Portland cement could be had for $8 per cubic yard paid in receiver's certificates, which at that time was equivalent to about $7 cash, a saving, therefore, of about 50% in the cost of the concrete over that of limestone masonry. The reasons for this reduced cost appear at once. With the concrete construction no derricks and hoisting plant were required, as would have been the case with masonry. The cost of this plant would have been high, as the work was spread out over such a large area and materials could be delivered only at the abutments. No derricks were even required in this case to set bridge-seats and cap-stones; for in the place of the former, ¾-in. steel plates were used, and the piers were finished on top by a steel plate 4 ft. square and ½ in. thick instead of using coping stones. Furthermore, for the concrete construction the commonest labor could be employed, in this case colored labor being used for which the contractors paid $1 per day of 11 hours' work. Since, therefore, a better substructure at a less cost could be obtained by using concrete instead of stone masonry, it was decided to build the abutments and piers required for this viaduct of Portland cement concrete. The author was thereupon employed by the railroad company as resident engineer to superintend the construction of the substructure.

The abutments were both built of the U design. The south abutment has a maximum height of 26 ft. from foundation to top. It is 25 ft. long at the bottom of the face, while the wing walls are each 28 ft. 6 ins. long at the top. The north abutment has a maximum height of 27 ft. from foundation to top, is 26 ft. long at the bottom of the face, and the length of the wing walls is 26 ft. 6 ins. at the top. The faces and sides of the abutments have been given a batter of 1 in. to the foot, and both abutments finish to a thickness of 5 ft. at the bridge seat, while the wing walls finish on top to a width of 3 ft. 6. ins. The piers were designed 4 ft. square on top, and the four sides have a batter of 1 in. to the foot. These piers vary in height from 5 to 16 ft.

On digging for a foundation for the various pedestals and abut-

ments, there was found in most cases a limestone rock at a depth of from 4 to 12 ft. below the surface. Where the piers rested on a rock foundation, the batter of 1 in. to 1 ft. gave a sufficient area of base. In the case of some of the piers at the bottom of the valley, where no rock was found at a reasonable depth, a good earth foundation was used, and the dimensions of the bottom were increased, so that in no case would the maximum pressure be greater than 1 ton per square foot. Where pockets of clay were encountered in the foundations, as occurred quite often, the material was excavated and the pockets filled with concrete.

After cleaning the bottom of all dirt and loose rock, the molds were built in place. These molds consisted of 2-in. tongued and grooved plank, braced by posts of 2 × 10-in. plank placed about 3 ft. center to center for the abutments, and at each corner for the small piers. At the corners one side was dapped into the other, so as to avoid any great leakage from the molds. The posts were then braced by batter posts from the surrounding earth. In the case of the piers a square frame was then dropped over the molds and securely spiked to the posts, to hold the mold well together. With the abutments the molds were built up as the work of laying the concrete progressed. In the case of the north abutment, the mold was built in 6 to 7-ft. sections, and held together by ¾-in. iron rods which passed through the concrete and which were left in the finished abutment. By this arrangement, much less planking was required, as the lower sections were taken off and used on the upper part of the structure as the work progressed.

The inside of the molds was painted with a thin coat of crude black oil, so that there would be no adhesion of the wood to the concrete. The same mold was used for a number of piers. Since all piers had the same batter, it was only necessary to add a few planks to the bottom of the old mold or to take a few away to bring it to the required height. In the case of the earth foundation before referred to, the pier was built in two parts, the upper portion having the same batter as the other piers, viz., 1 in. to 1 ft., and the lower portion having a sufficient batter to give the required area of foundation. The proportions of materials used in the concrete were 1 part cement, 2 parts sand, and 5 parts broken stone. The cement was the Atlas Portland brand. The best sand to be found in that locality was that

from the bed of the Tennessee River, which was used. The specifications for sand and cement were the same as adopted by the Department of Docks of New York City. Broken stone was obtained cheaply from railroad cuts, which were being worked at both approaches to the viaduct, the rock being crushed and used on the work. The rock was a strong limestone.

About ¾ yd. of concrete was made on each platform at a time, one barrel of cement being taken as the unit of measure; each batch containing 1 barrel cement, 2 barrels sand and 5 barrels broken stone. The method of mixing was as follows: 2 barrels of sand were spread out evenly in the mortar box and 1 barrel of cement was then spread over the sand. The mixing was done in the usual manner by hoes, and when completely mixed, about 12 galls. of water were added. The amount of water varied with the freshness of the cement and the temperature. The stone was measured in wheelbarrows, built with four sides, so that each one would contain one barrel. The stone was dumped and spread along the front of the box to a width of 4 ft. and a depth of 6 ins. After watering the stone, the mortar was thrown on it, and then both were well mixed by turning with shovels. Usually, when the material was twice turned, it was found to be sufficiently mixed to be shoveled into the wheelbarrows and taken to the molds. This shoveling the mixture into the wheelbarrows ensured its being well mixed, as it was thereby turned twice in addition to the previous mixing. The layers of concrete in the molds were from 8 to 10 ins. By passing the blade of a shovel between the mold and the concrete, a small portion of the cement mortar was forced against the mold, thereby giving the finished abutment a smooth appearance with no stones showing. In fact, the effect of this "cutting of the sides" has caused the criticism that the structures have the appearance of too rich a concrete having been used. The tamping of the concrete was done with rammers weighing from 30 to 40 lbs. Too much tamping is to be avoided, as it separates the mortar from the stone, bringing the former to the surface. An excess of water is also detrimental to the concrete, as it brings a layer of cement which has already set to the surface, forming a point of weakness in the finished block, unless it is well scraped off before the next layer is deposited. The upper surfaces of abutments and piers were finished with a ½-in. layer of mortar, consisting of 1 part of cement to 2 parts of sand. Two days after the

completion of the pier, the molds were removed, and the pier had the appearance of being one solid piece of stone. The concrete was protected from the sun's rays by twigs, and watered twice every day for a week after the molds were removed, as this was found to improve it greatly. One abutment contains 321 cu. yds. of concrete. In such large masses, as the work of laying the concrete had to be discontinued a number of times, it was found advisable to build the mass in sections, arranging them so that one section would always overlap the preceding sections considerably.

Before beginning work each day, the surface of the concrete previously laid was roughened with a pick, then cleaned and well moistened, a layer of mortar laid, and the new concrete deposited on this bed. When the molds were taken off it was found that where one day's work joined that of another, lines could be noticed, and in the case of the south abutment these lines were inclined, sloping at about the angle of repose of the wet concrete. At the north abutment temporary partitions were therefore inserted in the mold, and these lines became vertical, each section now being a trapezoidal block. After the concrete was set, some of these joints were cut into, and the concrete there was found to be as solid as in the remainder of the mass.

The non-porosity of the concrete was well shown by the following: On account of the delay in receiving the anchor bolts for the abutment, wooden cores were placed in the concrete in their stead. When the abutment was completed these cores were withdrawn and the holes filled with water and covered with boards and twigs, to protect them from the sun's rays. It was found that, after the concrete had set well, the amount of water in these holes lessened very slowly; in fact, the difference of the levels of the water, from day to day, could not be noticed.

A gang of men would mix and lay about 40 cu. yds. of concrete in a day's work of about 11 hours, when not delayed by lack of materials. The gang was made up as follows:

Filling sand barrels and handling water	1
Filling rock barrows	2
Mixing sand and cement	4
Mixing stone and mortar	4
Wheeling concrete	2
Spreading concrete in the molds	1
Tamping concrete in the molds	1
Foreman	1
Total	16

It was found from actual measurement that 1 cu. yd. of concrete well rammed and set, made up in the proportion by volume of 1 part cement, 2 parts sand and 5 parts broken stone (the broken stone being about 2 ins. in largest dimension), consisted of 1.25 barrels of cement, 10 cu. ft. of sand and 26.5 cu. ft. of broken stone.

The concrete was laid by contract; the price paid being $8 in receiver's certificates, equal at that time to about $7 cash. At this figure there was a small profit in the work in that locality, sand costing 30 cents per cubic yard, and cement $2 80 per barrel, delivered at the work. The total amount of concrete laid in the 36 piers and two abutments was 926 cu. yds.

DISCUSSION.

Mr. Morison. GEORGE S. MORISON, President Am. Soc. C. E.—There are classes of work which engineers prefer to have done by entirely unskilled labor rather than with skilled, because the former will do what is wanted and the latter will not. It is possible that for this reason the cheap negro labor was the best that could have been engaged for the work described in the paper.

Mr. Emery. CHARLES E. EMERY, M. Am. Soc. C. E.—Concrete has been used for reservoirs of considerable size in India, many of which are covered. A covered concrete reservoir was built with much care a number of years ago in Ceylon, but after a time large cracks appeared. An investigation was made, which indicated that they were probably caused by expansion due to temperature changes. A portion of the reservoir had been covered with earth before the cracks appeared, and the trouble was remedied by covering the entire reservoir with earth, so as to have all the concrete equally protected, and by closing the joints with cement covered with a preparation of asphalt.

Mr. Crowell. FOSTER CROWELL, M. Am. Soc. C. E.—Concrete is very largely used in hot climates with satisfactory results. Some years ago the speaker had occasion to examine the concrete retaining walls in use on the island of Jamaica, which had been in service for many years, and were found to be intact and in a fine state of preservation; they were important structures 30 to 40 ft. high in places, supporting a railroad embankment, and had been subject to great heat and to all the destructive influences of weather except frost. It is customary to consider the weak point of concrete to be the damaging effect of frost, but the speaker failed to see why this argument against concrete does not

apply equally to cut stone masonry. The effects on a mass of concrete produced by temperature or moisture are due to imperfections in mixing, and if the mixing and ramming are properly done, the arguments relating to moisture and freezing no longer apply. Mr. Crowell.

F. V. Abbot, M. Am. Soc. C. E.—The author's method of finishing the surface of the concrete so as to avoid cavities, by running a shovel down between the mold and the concrete, had been used by the speaker, but he considered as a better plan that employed by Captain Warren, Corps of Engineers, U. S. Army, at the gunlift battery at Sandy Hook, New York Harbor. The mortar for the concrete was prepared as usual, but a certain proportion of each batch was reserved for facing before the broken stone was mixed in. This mortar was placed along the bottom of the mold in a narrow pile sloping up against the sides as steeply as it would stand. The mold was then filled in with concrete up to about the level of the top of the pile of mortar, and the whole was rammed. The next batch of concrete was then added, but instead of filling it out against the mold the edges of the layer were sloped back from the mold at an angle of about 45°. When this batch had been spread and rammed the mortar reserved from it was placed in the triangular space left between it and the mold, and was carried up above the top of the layer, sloping back toward the sides of the mold again. In this way the mass was made homogeneous, and the surface smooth and true. The method was very rapid and insured the absence of stones near the face of the work so completely that there was no need of subsequent work to make it even and straight. Mr. Abbot.

On another part of the work the molds were taken down just as soon as the cement had set sufficiently, and a surface coat of mortar was then applied with a plasterer's float. This was much less satisfactory, and large pieces of the surface have scaled off. This will continue, because the mortars composing the coating and the concrete are of different compositions and have in consequence different rates of expansion and contraction with changes in temperature. A similar attempt to float or plaster the surface of concrete after it had taken a partial set failed at Fort Sumter, S. C.

Bernard R. Green, M. Am. Soc. C. E.—In building fortifications at Portland, Me., as long ago as 1872, the method of constructing concrete in a mold of planks, properly faced on the inside to prevent adherence of the concrete, was successfully practiced on a large scale. Where a very strong concrete was not necessary, American cement was used for it, but the exposed surface of such concrete was found to withstand freezing weather poorly and so was given a durable facing by plastering the inside of the mold a little in advance of the layers of concrete with a Portland cement mortar, which made an excellent protecting surface. These works have been exposed to the severe weather of that latitude for twenty years, and are still in good Mr. Green.

Mr. Green. condition. The method is entirely practicable and satisfactory if the fresh mortar and fresh concrete are not allowed to set separately, but harden into a monolith. The thickness of the Portland cement mortar coating in the fortifications probably varied from a small fraction of 1 in. to 4 ins., as no effort was made to produce a uniform coat, but simply to keep the stones back from the surface. A sufficient quantity was applied, however, to make an average thickness of about 2 ins. Concrete may be used as a substitute for stone or brick masonry up to the limit of the strength of the cement in any climate, when intelligently made and laid. Good concrete can be made with inferior materials and the cheapest labor under the direction of an engineer specially skilled in such work.

CORRESPONDENCE.

Mr. Parsons. WILLIAM BARCLAY PARSONS, M. Am. Soc. C. E.—The concrete work described in this paper is interesting from several facts. It is one of the largest pieces of pure concrete masonry used in railroad practice in the United States; the superstructure rests directly upon it without intermediate capstones; there was no cut stone used at all, the only stone used being the broken stone in the work; and it was put up very successfully by the most unskilled form of labor.

The valley was crossed originally by a high wooden trestle, which collapsed under a passing freight train three years ago. After the failure of the trestle, trains were run around the break by constructing a steep gradient on each side of the valley with a trestle of moderate height in the center. A year ago it was decided to replace the trestle with a steel viaduct. There was no stone along the line of the road fit for use in the masonry, the only variety being a limestone, which disintegrated after about three years of exposure.

As consulting engineer of the company, the writer therefore advised the use of concrete in the abutments and piers of the proposed structure. This recommendation met with strong opposition from the chief engineer and the superintendent of the road, who, while admitting the good quality of high-class concrete work, such as exhibited by the Department of Docks in the city of New York, nevertheless had a firm belief that as the contractors and laborers in the South were wholly unacquainted with the manufacture of first-class concrete, it would be impossible to make satisfactory work. The president of the road, however, followed the advice of the consulting engineer, relieving the chief engineer of the responsibility of the foundations and placing it upon the consulting engineer.

Bids were called for the work, and of all the contractors that bid but one was found who had sufficient courage to make a lower price on concrete than on cut stone masonry, and this bid diminished the

cost of the work several thousand dollars, the price that he named for the concrete being the exact amount that the consulting engineer had estimated. Mr. Parsons.

The consulting engineer placed the work in the hands of the author, who took charge of the contractor's men, none of whom had made any concrete, except the cheap lime concrete used in the foundations of small buildings in the South. The men, therefore, were of the most unskilled class possible. In spite of this, however, the author succeeded in constructing both the abutments and piers of concrete, the work comparing favorably with the best work that has been turned out by the Department of Docks in New York. In fact, the success was so great that both the engineer and the superintendent of the road have since admitted the excellence of the construction and are advising the use of concrete for future work, while the contractor who constructed the piers has stated that he will never use cut stone masonry again, if he can help it.

As another instance of the excellence of concrete, the writer desires to mention an experience with some piers for a bridge across the Wabash River, the superstructure of which he is now changing from wood to iron. Some years ago the stone masonry commenced to show signs of disintegration and the piers were incased in beton. The new steel bridge required the tops of the piers to be cut off, due to the change of bridge seat. It was found impossible to split or break the concrete, so that the workmen were obliged to drill holes and blow off the tops of the piers by small charges of gunpowder; in other words, the concrete was in far better condition than any stone masonry could possibly be.

GEORGE H. PEGRAM, M. Am. Soc. C. E.—The value of concrete for bridge piers and foundations is being generally recognized. The writer has used it unhesitatingly for very large bridges with as yet no indication of insufficient strength or want of durability. He has, however, heard of some cases of failure in other work, which could generally be explained on the ground of poor materials or careless workmanship. Mr. Pegram.

He has always used Portland cement, mixing it generally with sand and broken stone in the proportions of one, three and six. Sandstone is apparently better adapted for concrete than limestone. The mortar will hold to it more tenaciously, and it is free from incipient cracks which are apt to be present in limestone. Instead of screening the broken stone, it seems sufficient where sandstone is used to reduce the sand by the amount of detritus contained, thus reducing the cost without sensibly diminishing the strength.

The non-porosity of concrete, which the author's experiment illustrates, demands constant consideration in the execution of the work. Whenever construction is stopped for an interval of time sufficient to allow the mortar to take a partial set before work is continued, surfaces should be left rough and at right angles to the direction of sub-

Mr. Pegram. sequent pressures. On account of this non-porosity, it is very difficult to make plastering stick to these piers unless it is put on before the concrete has set, which is generally impracticable. It seems better to make the form tongued and grooved and surfaced inside, and then take precautions for keeping the stones from getting to the outside of the pier. This can be done by endeavoring to make the outside of the pier of mortar.

In large bridge piers, it is essential to put diagonal bracing from top to bottom to keep the forms in shape; otherwise a twist in the pier or other deformity may develop.

All cement used in concrete should be carefully tested before being used, and the effect of the water with which it is mixed should be carefully determined.

The appearance of the work is greatly benefited by the use of natural stone copings. Where these are used it is generally well to leave the lower bed rough, to give it a better hold on the concrete against lateral displacement.

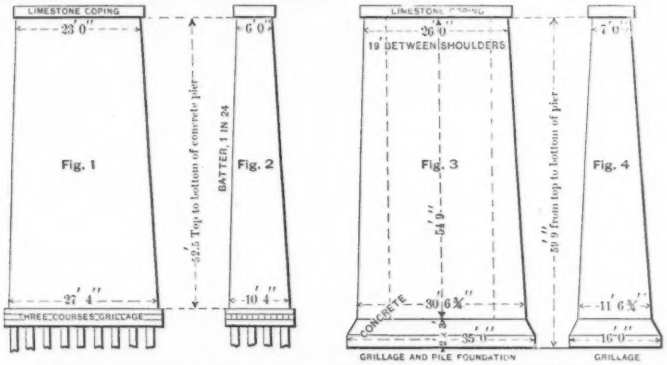
Mr. Gahagan. WALTER H. GAHAGAN, Assoc. M. Am. Soc. C. E.—In the correspondence on this paper Mr. Parsons says, "This is one of the largest pieces of pure concrete masonry used in railroad practice in the United States." The writer called the attention of George H. Pegram, M. Am. Soc. C. E., to this statement, and it was thought probable that much of the concrete work used for bridge piers in the South had not attracted attention, and that the majority of the members of the Society did not know to what extent concrete masonry had been used.

The bridge over the Arkansas River at Ft. Smith, Ark., has ten 200-ft. spans, and a 360-ft. draw span. The substructure for this work has thirteen concrete piers. This work was done under the direction of Mr. Pegram, the consulting engineer, as well as three other bridges, which were built in Louisiana in 1891, on the line of the Houston, Central Arkansas and Northern Railway. The writer was employed by the contractors, the Union Bridge Company, and had immediate charge of constructing the substructure for the Little River Bridge and the Red River Bridge, the latter crossing the Red River at Alexandria, La. These bridges were on the line of the railway just mentioned.

At Little River there were two piers built of concrete in the main channel which rested upon grillages and pile foundations, and two shore piers, which were two pair of cylinder piers. One of the concrete piers was 6 ft. wide by 17 ft. long between the shoulders at the top and had semi-circular ends. The batter was 1 in 24. The pier measured 52.5 ft. from the top of the concrete to the grillage. This pier contained 379 cu. yds. of concrete masonry (see Figs. 1 and 2). The other pier is a pivot pier carrying a girder draw span of 148 ft. It is 10 ft. wide and 12 ft. long between shoulders, with no batter but an enlarged base similar to that shown in Figs. 3 and 4. This pier

measures 51.9 ft. from the top of the concrete to the top of the grillage and contains 390.4 cu. yds. of concrete masonry. Mr. Gahagan.

The bridge across the Red River has six concrete masonry piers, all founded upon the natural ledge of rock. Three of these piers are 6 ft. wide at top by 19 ft. between shoulders, with semi-circular ends. Two of them, the draw rest piers, are 7 ft. wide by 19 ft. between shoulders at their tops, with semi-circular ends. The sixth is a pivot pier, a vertical shaft 27 ft. in diameter. The batter on these piers, excepting the pivot pier, is 1 in 24. The Red River piers measured from 44 to 53 ft. from the top of the concrete to the foundation. The quantity of concrete in them was 2 827 cu. yds.



At the same time they were under construction, the Union Bridge Company was building for the same company a bridge across the Ouachita River. This has five piers, two of them, the shore piers, being cylinders dredged down and filled with concrete. The channel piers are of concrete masonry resting upon grillages and pile foundations. The center pier is a pivot pier and carries a 360-ft. draw span. This pier is a circular shaft 27 ft. in diameter and measures 52.25 ft. from the top of the concrete to the top of the grillage. This pier contains 1 153.8 cu. yds. of concrete masonry. The draw rest piers are 7 ft. wide by 19 ft. between shoulders at the top of the pier. The batter is 1 in 24. These two piers contain 583.5 cu. yds. of concrete masonry each, and measure 59.75 ft. from the top of the concrete to the top of the grillage. The three piers contain 2 320.8 cu. yds. of concrete.

The total amount of concrete masonry in the piers for these three bridges is as follows:

Ouachita River crossing	2 320.8	cu. yds.
Little River "	769.5	"
Red River "	2 827.0	"
Total	5 917.3	"

Mr. Gahagan. The concrete for the Ouachita and Little River Bridges was mixed with a machine. That for the Red River crossing was mixed by hand in very much the same manner as described by the author, except the dry sand was first spread upon the platform, the cement spread evenly over the sand, and the cement and sand were then turned until they were thoroughly mixed dry. Water was next added and a mortar made. This mortar, when properly mixed, was spread out, and the broken stone thrown into it and the whole mass turned again two times before being put into the piers. The proportions used in mixing the concrete were 1 part of Portland cement, 2 parts of sand and 6 parts of broken stone. Figs. 3 and 4 show the long slender shafts, and certainly indicate that the designers and constructors of this work had no doubt but that concrete masonry was the only proper thing to use under certain conditions.

In 1892, on the Chicago, Rock Island and Pacific Railway extension through the Indian Territory, a bridge was built over the Red River near Doss, Tex., having piers entirely of concrete, no coping stone being used. The amount of concrete used in this work was over 3 000 cu. yds. The writer is at this time engineer and superintendent for the contractors who are building concrete masonry piers for a railroad bridge across the Arkansas River. More than 3 000 cu. yds of concrete masonry will be used. The proportions are 1 part of Portland cement, 2½ parts of sand, and 5 parts of broken stone.

Mr. Tuska. G. R. TUSKA, Jun. Am. Soc. C. E.—Mr. Abbot has suggested a method of obtaining a smooth surface "by placing the mortar along the sides of the mold." At the Lonesome Valley Viaduct, where the work consisted mainly of small piers with a large amount of exposed surface, this method would require so much more cement than by the method followed as to make a material difference in the cost, with no advantage over the surface obtained by "cutting the sides" as explained in the paper. There is also the disadvantage of the piers not being homogeneous throughout, which might cause the concrete to crack from the different rates in expansion. The method of plastering the sides after the concrete has partially set is a poor one and not to be recommended, as in every case the author has seen it has caused the surface to break away soon after setting, on account of the differences in the rate of expansion of the materials.

As to the effect of frost on the structures. It is now a year since these masses of concrete were made. They have gone through hot dry weather and also freezing weather since erection, but no bad effects have been noticed. In fact, not even the sharp edges of the pedestals, etc., have been broken off. All the masses of concrete are in as good condition as when first erected, and no trouble of any kind has been experienced since completion.